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A TECHNICAL UNIVERSITY.

From drawing-room meetings we have hitherto expected little: so much has been heard of them in association with that class which plays at philanthropy and practices benevolence as a pastime, that a feeling of disgust has been the most prominent sentiment to which they have given rise. Now, however, perusal of a memorandum, "printed for private circulation," of proceedings at a remarkable gathering at St. John's Wood, has afforded proof positive to our minds that even a drawing-room meeting may be constituted for a higher purpose than the discussion of trivialities or indulgence in mock heroics. Not alone was the character of the meeting to which we allude remarkable: there were those amongst the men and women assembled in Mr. Robins's drawing-room who are destined to attain, if they have not already attained, the highest eminence in the world of science and technics. The chief actors in that interesting scene formed a group of men whose labours, although they themselves are for the most part still in the prime of life, have been such as to place them in the very front rank of earnest practical workers, and to stamp them as men of energy and capability, men of deep thought and great power of execution, men possessing active minds and willing hands. And here they had met to discuss, in thorough earnestness, even with enthusiasm, a question which is of nothing less than national importance, notwithstanding that by the nation it has been to a great extent neglected. Professor Huxley presided, and Professor Ayrton lectured. The lecture nominally was on "The Technical Training at the Central Institution:" but Professor Ayrton's carefully-prepared remarks opened out considerations of far wider significance than can attach to a single effort to impart instruction of a technical character. Not that the Institution which supplied the lecturer with a text is in any sense merely local or confined in its operations: it is intended, as its name implies, to be central in its character, and although not centrally situated so far as the Metropolis is concerned, a misfortune which was probably unavoidable, it yet must inevitably become the great centre to which will gravitate the most earnest of those who are seeking to obtain a deeper insight into the mysteries of natural science; it must, if it be not continuously "starved" and therefore limited in the distribution of its benefits and the extension of its powers of usefulness, become in time a kind of technical and scientific university, to be regarded by students in local institutes and colleges as the great universities of Oxford and Cambridge are regarded by public schoolboys of to-day. Then, perhaps, will arrive that long-desired era when England will be self-dependent for her technical instruction as for her classical education, and engineering students will no longer leave these shores to pursue in German universities studies which they are prevented from following here by the deplorable lack of facilities. But Prof. Ayrton did not attempt to confine himself to a description of what takes place at his great Kensington Institution. He courageously addressed himself to the fundamental question, which is becoming more and more pressing in its demand for solution, of the relative importance to the average youth of classical and of technical knowledge. The view advocated by Prof. Ayrton—a view in regard to which his hearers were in perfect accord with him—may be readily divined: he was far from decrying the importance of the classics, or of mathematics, pure and simple as distinguished from applied; but was strongly opposed to the perpetuation of the system of education which bestows a preponderating amount of time and pains upon studies which are likely to be the least useful. To quote one of his pregnant sentences: "When science was practically unheard of it might perhaps have been profitable enough to study how from one known fact an equally well-known fact could be deduced; but life is not long enough for that now." Knowledge, the lecturer further said, has increased very much more rapidly than our brain capacity, and he was delighted to see that the universities are at length becoming aware of the fact and endeavouring to emancipate themselves from the state of intellectual thraldom under which they have been so long labouring. He did not decry the study of mathematics; what he opposed was the study of mathematics as an end. Mathematics is one of the most useful and powerful weapons the natural philosopher possesses, but—and this is a capital illustration of the lecturer's aptness in analogy—it is no use spending all one's time making guns and learning how to load them, if they are not now and then to be fired off. Professor Ayrton would settle the difficulty with regard to mathematics in a very simple but a decidedly comprehensive manner. While mathematics is being taught in one part of a school or college, he says, its use should be taught in another. This seems a very reasonable plan, and one which would in all probability operate in the way which the professor anticipates; that is to say, the student, finding how valuable mathematics is to him in the practical side of his work, would become the more eager to master it. The object in extending the system of technical education should be, as he held, that not only should the practical man be trained to use his brain when he used his hands, but the scholar also should learn to use his hands when using his brain. He believes the age which is now little more than in its dawn—an age in which science is being made comprehensible and therefore useful to practical people—will in the future be as much regarded as a period of the people's awakening as is

the Elizabethan era now. His progressive and eminently practical mind could conceive nothing more gratifying than to see the man who had previously constructed or superintended the construction of machines, studying the fundamental principles underlying their action, side by side in the laboratories with the University student who was enlarging his limited mathematical notions by experimentally finding out how those notions are modified in actual practice, and how things that are for simplicity regarded as constants in books are variables in nature. In a word, he rejoices that at length the fact is being admitted that in addition to the duty of bringing science to practice, technical education has another equally important duty to fulfil, that of bringing practice to science. His views are embodied, as might have been supposed, in the methods and policy of the Central Institution, which institution, we may say, owes a large measure of any success it may have already obtained to the energy and enthusiasm of Professor Ayrton. The greatest difficulties in the shape of organisation have been overcome, and there seems no limit to the degree of usefulness possible to this institution, provided only it be well supported by those who have given it being. The City and Guilds have been so generous heretofore in furtherance of the objects of technical education, that it may reasonably be supposed they will not hold their hands when they are made to see that the latest and noblest development of their scheme languishes for lack of the one necessary for a fully useful existence. When the site of the projected Imperial Institute was under discussion, the Central Institution was pointed to as an instance of the folly of going to South Kensington ; vast sums, it was said, had been expended in the equipment of this ambitious establishment, with the result that only a paltry dozen or so of students had been attracted to it. Whatever may be the prevalent opinion as to the wisdom of locating the Central Institution in Exhibition Road, it must be confessed that a quite sufficient answer has been given to the cavillers who have questioned its success. It is true that £100,000 were spent in the erection and equipment of the Institution, but that is a sum which, looking to the fact that it is placed in "the largest town in the world," and in the midst of a population of something like four million souls, appears small by comparison with the sums spent on similar institutions on the Continent of Europe. Mr. Robins's new book points out that the cost of erecting the Polytechnic Schools of Zurich, Munich, Vienna, Stuttgart, Dresden, Hanover, Carlsruhe, Aachen, Berlin, Delph and Moscow, and the Mining School of Freiberg has been over three millions sterling, so that the average cost of each was over £250,000. The average cost of maintaining each of these schools is £17,000 per annum, a sum nearly twice that annually expended on the Central Institution. The statements which placed the number of students at 17 or 20 have been met with a flat denial. There are 81 students attending the regular courses, and 180 other students attending the special courses on the "Testing of Dynamos and Motors," "The Chemistry of Nitrogen Compounds," and on "Wood-working Tools," whilst 230 additional students of one kind and another are expected after Easter. To Professor Ayrton it seems that the City and Guilds of London Institute, in fitting up laboratories with all modern appliances have invested money which will bear a very high rate of interest for the country's welfare ; and in this view he is supported by Professor Huxley, who says that if in the course of the next ten years the City and Guilds Institute can succeed in catching and training another Faraday or Whitworth or Armstrong, he will from a mere commercial point of view be worth all the expenditure. Departing again from the questions affecting the Central Institution, Professor Ayrton brought an indictment against the industries of this country which cannot be considered without exciting great uneasiness. Having referred to some recent utterances of Professor Huxley, who asserted that the latter years of this century promise to see us embarked in an industrial war of far more serious import than the military wars of its opening years, the lecturer said :—

"Well, Darwin has shown us what is the result of a struggle for existence ; it leads to the survival of the fittest. Now, are the English people the fittest ? What about the lace curtains, the web of which is made in England, but which, before they can be sold in England, have to be sent to France or Belgium to have the pattern put on, because we have not the requisite machinery ? What about the steamers built on the Clyde for the German nation, and which as soon as they can just float are manned by a crew sent from Germany, and taken over to that country to have their interiors fitted, because this can be done better and more cheaply in Germany than in England ? What about the watch industry ? In 1856, I believe it was, England made watches for the whole world, and now it imports large numbers yearly from Switzerland and America. I shall, perhaps, be answered that that is because Continental workmen will work for a pittance that English workmen scorn, but does that apply to the Waltham watch, the Waterbury watch ? Is America so noted for low wages ? . . . . . No doubt we are handicapped by the fact that vast sums have been spent in machinery in England, which our manufacturers are loth to discard, even although it will only turn out articles that have gone out of date and which are totally unsaleable. And curiously enough some prefer to continue making these articles (and to regard the want of business as due to over-production) to laying out capital on new modern machinery which a country taking up the industry starts by buying. But this is not a sufficient explanation. England has money enough to make or buy the very best machinery when it recognises the importance of having it ; and one of the results of the technical education which the manufacturers' sons, who are beginning to come to the Central Institution, are receiving there, will be to bring about a recognition of the fact that not only to maintain the lead, but even to keep directly in the front, not merely the men but also the manufacturers must arm themselves with technical knowledge to enable them to effect the improvements in their machinery and processes which progress demands of them."

This is a view of the subject upon which not only manufacturers but the Government itself would be wise to bestow careful attention. But until some great national effort is made, we can do no better than wish Prof. Ayrton and his colleagues all success in their efforts to make practical people scientific and scientific people practical.

PRACTICAL NOTES CONCERNING THE CONSTRUCTION, USE AND MANAGEMENT OF STORAGE BATTERIES.

By A. RECKENZAUN.

(*Continued from page* 304.)

Rise of E.M.F. when charging secondary batteries.—At the commencement of the charge the E.M.F. required is very little more than 2 volts per cell, but as the operation proceeds this E.M.F. increases, until at last, when gases are given off freely, it may rise to 2·5, and even more per cell, according to the charging *rate*. The dynamo, therefore, will have to be so constructed that if it had to charge fifty cells in series it should be capable of giving 125 volts at the terminals of the battery. Assuming that the speed of the generator is constant, the current will also remain nearly constant, for when at the commencement of the charge the counter E.M.F. of the cells is low, their internal resistance is correspondingly high, consequently these two influences partially counteract each other. We have seen from fig. 4, page 219, that the specific gravity of the acid rises and falls in proportion to the amount of current sent through the cells, or withdrawn therefrom, and that the "curves" traced by plotting the hydrometer readings are practically straight lines. The rise of E.M.F., however, does not appear to occur in exact proportion to the amount of charge put into the cells, as will be observed from the curve, fig. 6, which was constructed by Messrs. Drake and Gorham to illustrate certain statements in a paper read at the British Association meeting of 1886. This curve shows the rise of E.M.F. during the charge, the current being throughout kept constant at 22 ampères. It will be seen that at the commencement the charging E.M.F. was only 2·02 volts, that after 220 ampère-hours had been put in, representing about one half the capacity of the cell experimented upon, the E.M.F. had risen to 2·13, and that when the cell was giving off gases freely the E.M.F. was as high as 2·53 volts. This curve does not by any means represent a proportional augmentation of pressure; for in the first hour a rapid rise of E.M.F. takes place, then it goes on gradually until the thirteenth hour; for the next seven hours the pressure goes up very fast, and during the last hour no perceptible change takes place, indicating that the cell was fully charged with 462 ampère-hours. This shows clearly what provision must be made in dynamos for use with secondary batteries when the current is to be kept constant. Sir Thomas S. Bazley suggested, in the ELECTRICAL REVIEW of March 19th, 1886, that the charge of secondary batteries can be tested not only by the hydrometer, but by the alteration (the dynamo speed being constant) of both current and E.M.F. He considered that the gradual rise of E.M F. during charging is an unfailing indication of increased storage; at any rate, when a certain reading of the voltmeter (determined by previous trials) has been attained, no further efforts of the dynamo can augment it; and it is, therefore, fair to assume that this maximum E.M.F. corresponds to a full charge of the battery. In order to ensure that the voltmeter readings really correspond to the amount of charge, it will be necessary to count the number of revolutions of the dynamo each time such readings are taken; this involves more trouble, and it is, perhaps, less accurate even than the hydrometer test.

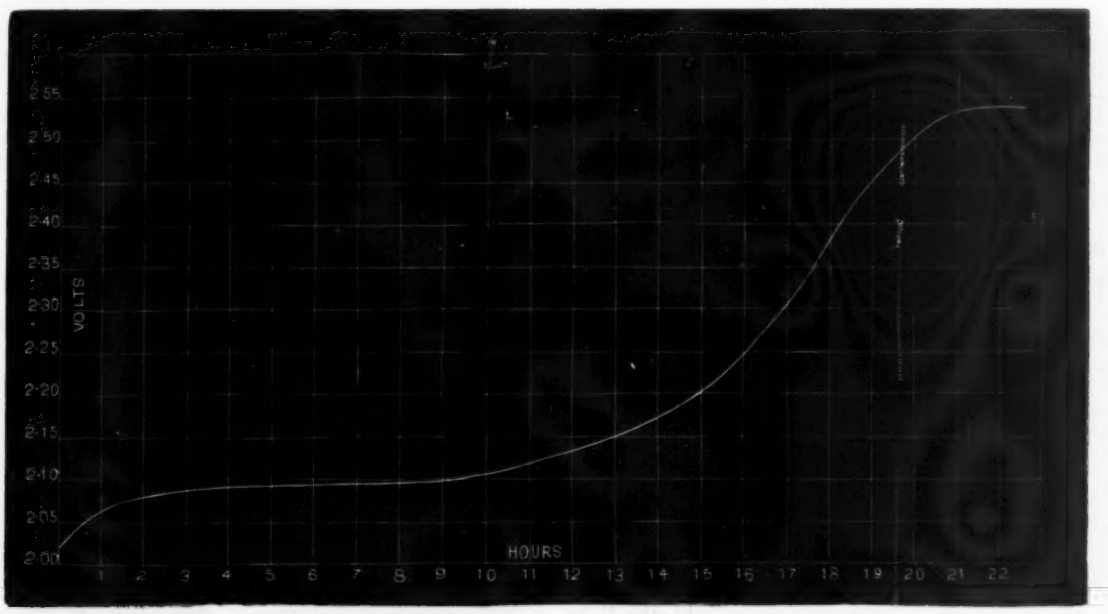


FIG. 6.

Variation of E.M.F. with generator running whilst the battery is discharging.—We have seen, from the results tabulated on page 304, that within certain limits the E.M.F. of a shunt-wound dynamo will adjust itself to the counter electromotive force of the cells which it charges, and as this counter E.M.F. is increased, the speed being constant, so the current rate was diminished, and *vice versa*. We have also observed from experiments collected in tables I. and II. that the E.M.F. of a battery varies with the rate of discharge.

Secondary batteries can only be charged, safely and conveniently, by means of dynamos having a constant magnetic field, such as shunt machines, magneto machines, or dynamos whose field magnet coils are separately excited. But such dynamo machines do not give a constant E.M.F. when the external resistance, or, what comes to the same thing, the current rate is varied within wide limits. In the case of electric lighting installations the accumulator is coupled in parallel with the dynamo, and it frequently occurs that the latter is kept running whilst the cells supply current to the lamps; one, in fact, supplements the other. Now, so long as the number

of lamps in use is constant, the E.M.F. of the dynamo and with it the cells will be constant, but when more lamps are switched on, demanding a greater current, then the E.M.F. of the dynamo will fall in proportion to the slightly diminished counter E.M.F. of the cells. To explain this, we take two extreme cases: the dynamo, for instance, is giving 40 ampères; if a current of 1 ampère were flowing through the lamp circuit, 39 ampéres would have to go into the cells, and when 39 ampères are required by the lamps then only one can be utilised by the cells; in the latter case, owing to the diminished resistance of the lamp circuit, the E.M.F. of the generator will fall very considerably unless the resistance of the battery is very much less than that of the lamps and leads.

In practice the battery resistance is always less than one-tenth of that of the lamps, consequently there is a large margin for compensating any irregularity. Mr. Augustus Littleton, in his extensive installation at Sydenham, has made some interesting experiments on this point, also published in the REVIEW of May 19th, 1886. There we find that, when the dynamo was running at 600 revolutions per minute in conjunction with the accumulator, the E.M.F. was 117·5 volts with 16 ampères, 110 volts when using 38 ampères, and only 96·5 volts at the moment when a current of 62 ampères was flowing through the lamp circuit. The resistance of the armature is stated to be ·119 of an ohm, and this no doubt has a great influence upon these fluctuations; if this resistance were less, then a more uniform result could be obtained, but this great variation in the E.M.F. as the current rate is altered, the makers of the dynamo declare, is "the proper condition of things required for charging accumulators when the power is supplied by a gas engine (as in the case of Mr. Littleton's), or by any prime mover where the delivery of power is in the nature of emphasised intermittent pulsations."

Sir David Salomons, whose wide experience in the application of secondary batteries for electric lighting is universally recognised, says "the action of the cells in steadying the light, when the prime motor is irregular in speed, depends on two conditions, one acting when the cells are charging, and the other when the dynamo is running and doing work on the lines, but sending very little or no current into the cells, or when the cells are discharging to line at the same time, which is the case when the E.M.F. of the dynamo and the cells are equal. Sir David calls this latter condition "the balancing point," and he also contends that the steadiness of the light (or E.M.F.) depends on the relation between the resistance of the cells to that of the line, and on the "characteristic" of the dynamo. The less the resistance of the cells and the steeper the "characteristic curve," the steadier will be the light during charging.

(*To be continued.*)

ELECTRICAL DISTRIBUTION BY ALTERNATING CURRENTS AND TRANSFORMERS.

By RANKIN KENNEDY.

(*Continued from page* 299.)

TRANSFORMERS—*Continued.*

THE Zipernowski and Deri ring transformers, consisting of an inner core of two insulated conductors, one of which forms the primary circuit and the other the secondary circuit of the transformer, with an outer sheathing of iron wire forming the magnetic circuit of the transformer, is shown in the finished form ready for use, fig. 11. The terminals at the bottom are the secondary; the terminals at the top are the primary; the four terminals at the top are for the purpose of conveniently inserting two fuses in the primary circuit to protect the fine wire from accidents, such as short circuits in the secondary circuit. This form of transformer leaves nothing to be desired in the matter of simplicity and efficiency, but a slight fault in the circuits inside cannot be rectified without the complete undoing of the whole affair. The magnetic circuit has an extremely low magnetic resistance, being short and of great cross section; therefore self-regulation is perfect, and the heating of the iron arising from the rapid reversals of its magnetism is dissipated from the large outer surface exposed.

FIG. 11.

In fig. 12, I have shown a Dick and Kennedy transformer of the subdivided type in its complete form. In this transformer the magnetic circuit is of the lowest possible resistance giving perfect self-regulation. The core, *g*, *g*, is formed of laminated iron having spaces cut out as shown at fig. 13. Into these spaces are wound

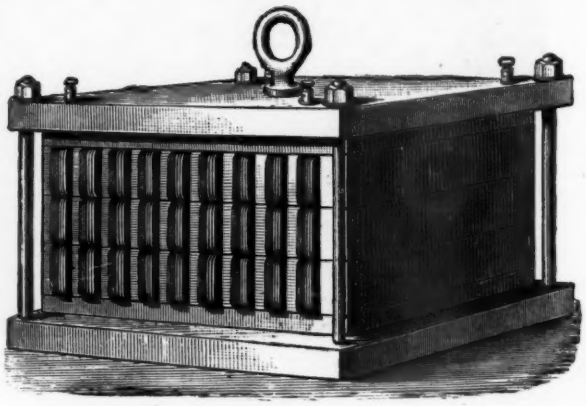


FIG. 12.

the primary and secondary wires, so that each forms a complete little transformer, having its own short magnetic circuit independent of the others. A number of cores containing any number of transformers may be piled one on the other, the bottom of the pile commencing with a laminated plate, *h*, ending with another laminated plate on top; a fault occuring in any of the little transformers does not entail the undoing of the whole, in fact, a fault in one of them may be cut out while working by short-circuiting it across or cutting it out of the circuit altogether.

The arrows in fig. 13 indicate the short path of the magnetic currents. It will be seen that this transformer is a further development of the Pacinotti ring, and it is now necessary to point out this departure in making transformers as commencing a new type. We have first Faraday's transformer, a plain iron ring enclosed by two conductors, then in my ring transformer of 1883 we have the same things, with wires or conductors subdivided into many sections, all having a common core or magnetic circuit. In the Ferranti we have the same things again with

the additional outer and inner magnetic sheathing, but still the magnetic circuits are common to all the coils or sections of the primary and secondary.

In the Pacinotti ring, with the sheath of iron wire as made by me, we have an iron core carrying the two conductors in sections; but each section has its own independent magnetic circuit. Fig. 14 shows a complete transformer on this plan.

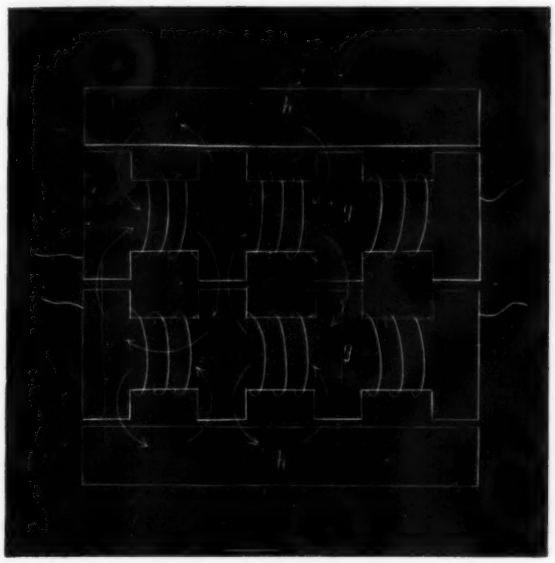


Fig. 13.

In fig. 12 this new type of transformer is more perfectly put into practice, and there are other methods than this of carrying it into practice, so that we may conveniently call this type the sub-divided transformer to distinguish it from those types having a magnetic circuit common to the whole of the two circuits of the conductors.

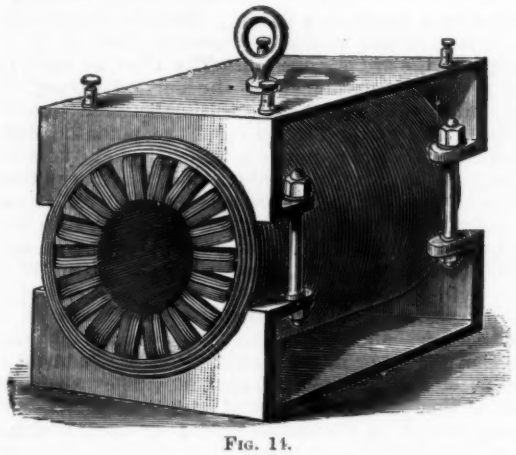


Fig. 14.

The chief advantage of the subdivision of the magnetic circuit is that it obviates the use of long magnetic circuits, and also the magnetic lines of force in the circuits are of very low density, being that due to the conductors enclosed by it only.

The ideal sub-divided transformer contains a great number of small magnetic circuits, each enclosing one turn of secondary wire and 10, 20 or 30 turns of primary wire as the desired ratio of reduction of potential may require.

Transformers of potential are here classed, according to their magnetic circuits, into three types:

Faraday types. Closed magnetic circuit common to all the coils or sections.	Faraday, 1835. Kennedy, 1883. Ferranti, 1885. Zipernowski and Deri, 1885. Stanley, 1886.
Ruhmkorff types. Magnetic circuit closed through air.	Ruhmkorff, 1842. Gaulard and Gibbs, 1884. Jablochkoff, 1876. Fuller, 1878. And many others.
Kennedy type, 1886. Magnetic circuit sub-divided so that each section has a complete magnetic circuit of its own.	The Pacinotti ring with sheath. The square pile of coils on grooved core (fig. 12).

(To be continued.)

JOLIN'S POCKET GALVANOMETER.

This handy little instrument is shown by the figure. The coil has two wires wound on it, one fine and the other coarse. The fine wire is wound on the bobbins first, and connected, one end to the case and the other to the right hand terminal. The thick wire is connected from the case to the left hand terminal. The wires are so arranged that if the wire from the copper pole of the battery is connected to the case and the wire from zinc is connected to the terminal, marked Z, the needle at once points to that terminal, thus telling the direction of current. The two circuits are so arranged that if the battery wires are connected to the terminals the current acts in the same direction and increases the deflection. The fine wire is 200·6 ohms and the thick wire ·65 ohms—total, 201·25 ohms. The ordinary pattern as used by the telephone companies is wound

to 20 ohms, the instrument is $1\frac{7}{8}$ inch diameter and $\frac{5}{8}$ inch thick—the size of a Waterbury watch—and is so constructed that on taking out two screws the complete works can be removed for replacing a broken glass without disturbing any part, and all the working parts can be examined without taking to pieces. It can, of course, be wound to any specification, and will do for all the work for which an ordinary lineman's detector is used, but with the great advantage of being really portable; it can be carried on the watch chain as a watch.

ON AN ARC LAMP SUITABLE TO BE USED WITH THE DUBOSCQ LANTERN.

By PROF. SILVANUS P. THOMPSON, D.Sc.*

The lamp devised by Foucault and Duboscq, and supplied for so many years by the famous house of Duboscq, fails to fulfil the electrical requirements of the modern physical laboratory, though it has rendered

* Communicated by the Physical Society to the *Philosophical Magazine*.

excellent service in the past. Yet the lantern and optical adjuncts of the standard pattern of Duboscq are so widely used that it seemed desirable to find some other arc lamp which, while fulfilling the electrical requirements of the case, could be used with the Duboscq lantern.

Before describing the lamp which I have for 12 months employed for this purpose, I propose to state the conditions to be fulfilled, and the reasons why the old Duboscq lamp fails to fulfil them.

The modern physical laboratory is usually supplied with electric energy under one of two alternative conditions, namely, either at constant potential or with constant current; more usually under the former condition. If supplied from a dynamo the dynamo may be either series-wound, shunt-wound, or compound-wound. If supplied from accumulators the accumulators will work at constant potential, and will have a very small internal resistance.

The arc lamp for laboratory use must be capable of working under the given conditions. No doubt the Duboscq lamp worked fairly when supplied with current from 50 Grove's cells. But in a laboratory where there is another and better and less wasteful source of supply, 50 Grove's cells are not desirable. Though 40 accumulators have an electromotive force almost exactly equal to that of 50 Grove's cells, the Duboscq lamp does not work well with them unless a resistance of several ohms is intercalated in the circuit to represent the internal resistance of the Grove cells; and even then the Duboscq lamp does not, for certain reasons, work as satisfactorily as the lamp to be described, and its cost is about three times as great.

In every arc lamp for optical purposes there must be mechanism adapted to perform the four following actions:—

1. To bring the carbons together into initial contact.
2. To part the carbons suddenly, and with certainty, to a short distance—about three millimetres—apart. This action is technically called "striking" the arc.
3. To supply carbon as fast as it is consumed, by moving one (or both) of the pencils forward into the arc. This action is called "feeding" the arc.
4. To so move the carbons, or their holders, that the luminous points retain the same position in space at the proper focus of the optical system. This action is called "focusing" the arc.

It may be remarked, in passing, that the feeding mechanism of many lamps also performs the action, set down as No. 1 of the above, of bringing the carbons into initial contact preparatory to striking the arc.

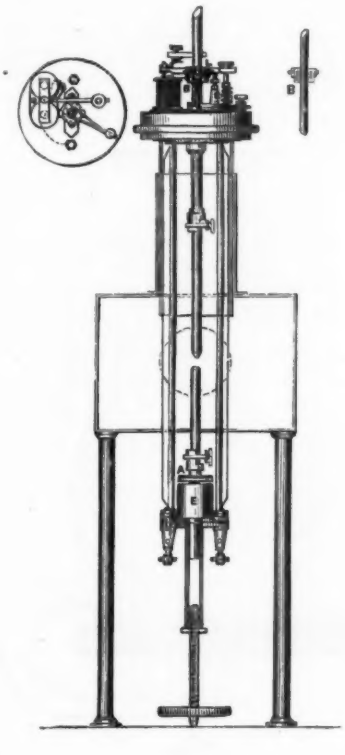
In many arc lamps the attempt is made to unite the striking and feeding mechanisms in one; but in many lamps, and in the one I have to describe, the striking and feeding mechanisms are distinct. The striking mechanism in all the arc lamps of commerce consists of an electro-magnet or solenoid arranged in the main circuit of the lamp, the armature or plunger of the same being mechanically connected with one or both of the carbons, so that when, by the turning on of the current through the touching carbons, there is a great rush of current, the attraction of the electro-magnet or solenoid shall instantly part the carbons and strike the arc. In the majority of the commercial arc lamps it is the upper carbon only that is raised to strike the arc; in a few other lamps, and in the one I am using, the lower carbon is depressed. In one of the older patterns of the Duboscq lamp the lower carbon was also thus directly acted upon, its holder being attached to the armature of an electro-magnet beneath it. The same is true of the Serrin lamp. But in the Duboscq-Foucault lamp the arc is struck in a different way. The two carbon holders are connected by racks to a clockwork gearing which either parts them or brings them together, the movement being driven by a double train of wheels, either of which can be released in turn. The weight of the upper carbon holder drives the train that moves the carbons together: a coiled spring drives the train that parts the carbons. Whether either of the trains, or neither of them, shall be released is determined by the position of a double-toothed detent which, placed between the final spur-wheels of the two trains, locks both of them when in its mean position, but releases one or other when shifted to right or left. The position of this detent is determined by the current through the lamp, it being attached to one end of a three-arm lever, the two other ends of which are respectively attached to the armature of the controlling electro-magnet and to an opposing spiral spring. When the moment of pull of the electro-magnet upon its armature is greater than that of the opposing spring, the detent is pulled over one way, releasing the approximating train of wheels while retaining locked the parting train. When the moment of the pull of the opposing spring exceeds that of the electro-magnet on its armature, the detent is pulled over the other way, locking the approximating train and releasing the parting train. When the pull of the electro-magnet exactly balances that of the opposing spring, both trains are locked. Now when the current is at first turned on, there is a sudden pull upon the armature of the electro-magnet; but the carbons are not instantly parted, partly because of the inertia of the train of wheels, and partly because of the backlash of the mechanism. Two or three seconds may elapse before the arc is struck. This delay is serious, either when working with dynamo or with accumulators. If the dynamo is shunt-wound, the short-circuiting even for this short period demagnetises the field-magnets. If the dynamo is series-wound or compound-wound, or if accumulators are being used, there is overheating during the period of delay. Supposing, however, the arc to be struck, then the inertia of the train of wheels makes itself evident in another way; for it parts the carbons too far, producing a long arc of considerable resistance; and as the current then drops below its normal value, the armature goes over the other way, and the other train of wheels is momentarily released. This alternation between the two trains, which often lasts for some time, produces a disagreeable instability.

The feeding mechanism of arc lamps next comes in for consideration. The object of the feeding mechanism is to supply carbon as fast as it is consumed, and so keep the light constant. But the light cannot be kept constant unless the consumption of electric energy in the arc is constant. The electric energy is the product of two factors—the current through the arc, and the difference of potential between the electrodes. Calling the current i and the potential difference e, it is the product, $e\ i$, which is to be kept constant. Now, as remarked at the outset, the very conditions of modern electric supply are that either e or i is maintained constant, the usual arrangement in commercial lighting being i constant for arc lamps in series and e constant for glow lamps in parallel. One of the two factors being a constant by the conditions of the supply, the other factor must be kept constant by the feeding mechanism. Or, in other words, the variations of the other factor should be made to control the action of the feeding mechanism. The mechanical part of the feed may consist of a train of wheels driven by the weight of the carbon holder or by a spring, or it may consist of a friction-clutch holding the carbon from sliding forward, or of a worm-gearing or any other; but it must be controlled by an electric mechanism of one of the two following kinds. For keeping i constant, the feeding mechanism must be controlled by an electro-magnet (or solenoid) placed in the main circuit, working against an opposing spring or weight. For keeping e constant, the feeding mechanism must be controlled by an electro-magnet (or solenoid) placed as a shunt to the arc, and working against an opposing spring or weight. In the latter case, if for any reason the arc grows too long, the potential at the terminals will rise, more current will flow around the shunt, which will then overcome its opposing spring (or weight), and will release the feeding machinery until balance is restored. The use of the shunt, introduced first by Lontin, enables arc lamps to be connected two or more in series in one circuit. A less perfect solution is the differential principle in-

troduced by Von Hefner Alteneck, where the difference between the attractions of a series and a shunt-solenoid maintains constant, not the product, $e\ i$, but the difference $e - i$.

The only perfect solution of the problem is a feeding mechanism which, by combining in itself a shunt coil and a series coil, shall keep the product $e\ i$ a constant, however either factor may vary. All the commercial arc lamps for lighting in series have shunt circuits to control the feeding mechanism; though often the arrangement takes the form of a shunt coil wound (differentially) outside the series coil of the striking mechanism; so that feeding is accomplished by the shunt coil demagnetising the striking electro-magnet and momentarily up-striking the arc.

Returning to the Duboscq lamp, it may be observed that, as it possesses no shunt-coil, it can only feed by a weakening of the current in the main circuit. Hence it is obvious that a Duboscq lamp cannot possibly work in a constant current circuit. Also two Duboscq lamps will not work in series with one another, as their individual feeding is not independent of the other. Neither will two work in parallel with one another;



for the weakening of the current in one throws more current through the other, and the instability before alluded to—called "hunting" by electric engineers—becomes yet more pronounced.

The lamp that I have adapted to the Duboscq lantern is one known in commerce as the "Belfast" arc lamp, its principles of construction being due to Mr. F. M. Newton*; but I have had the design altered to suit the special work. In this lamp, as previously mentioned, the striking and feeding mechanisms are separate. The arc is struck by means of an electro-magnet, E, of the tubular pattern, having as its armature an iron disc, A, which, when no current is passing, is held up by a short spiral spring at about three millimetres from the end of the electro magnet. The lower carbon holder is mounted upon this disc, so that the arc is struck by the downward movement of the lower carbon. The feeding mechanism is both simple and effective. The upper carbon holder is a long straight tube of brass: it passes through a collar in the frame of the lamp, and also through a metal box, B, above. This metal box contains a piece of curry-comb with the steel bristles of the comb set to point obliquely inwards and downwards. They grip the carbon holder and allow it to be pushed downwards, but not upwards. The box itself is mounted upon a strong brass lever, L, close to the point of the lever. One end of this lever is drawn downwards by an adjustable spiral spring, S, whilst the other carries an iron armature which stands immediately above the poles of an electro-magnet, which is wound with fine wire and placed as a shunt to the lamp. Above the lever there is a contact screw, platinum tipped, making contact with the lever, exactly as in the ordinary trembling electric bell, and the lever and contact screw are included in the shunt circuit. The attraction of the shunt magnet for its armature is opposed by the pull of the spiral spring. Whenever, by reason of the resistance of the arc, a sufficient current flows through the shunt circuit, the opposing spring is overcome, and the lever is set into vibration like the lever of an electric bell, but more rapidly. The vibratory motion is thus communicated to the box containing the steel wire comb, which at once, by an action well known in mechanism, wriggles the carbon holder downwards by innumerable small successive impulses. So soon as the motion of the carbon has reduced the resistance of the arc, the shunt circuit diminishes and the feeding action ceases, to recommence when required. It is found best for lantern purposes to send the current upwards through the lamp, the lower carbon being the positive one. A thick cored carbon of 13 to 15 millimetres diameter is preferred, as it gives a good luminous crater and burns slowly. A 10 millimetre copper-plated carbon is used for the upper electrode, and it is adjusted so that its centre falls slightly in front of the centre of the lower carbon, thereby causing the crater to send its light forward.

The lamp as used in commerce has no focusing arrangement. In adapting it to the Duboscq lantern, the frame was made narrow; so that when the inner chimney of the Duboscq lantern was removed, the lamp could be dropped entire down the outer chimney, a metal sleeve of the same diameter as the inner chimney being added to the lamp as a guide. At the bottom of the lamp a gun-metal tube was added, tapped inside with a screw thread, into which works a steel screw having a small hand-wheel near its lower end and a pointed pivot at the extremity. The lamp slides down the chimney of the lantern until the pivot touches the base-board. When the arc burns down the lower carbon, so that the luminous crater is no longer in the optical focus, a turn given by hand to the wheel suffices to raise it to the proper position; but the lamp will burn for ten minutes without requiring any readjustments on this account. The lamp shown to the Physical Society was constructed by Mr. E. Rousseau, Instructor in the Physical Workshop of the Finsbury Technical College, assisted by Mr. A. D. Raine, now Demonstrator in the City and Guilds Central Institution.

* See Electrical Review for October 18th, 1884.

Fatality to Telephone Lineman.—At St. Bartholomew's Hospital on Monday Mr. S. F. Langham held an enquiry into the circumstances connected with the death of Thomas Jarman, a labourer in the employ of the United Telephone Company. Walter Goddard, telephone labourer, deposed that on the previous Friday morning, at about 11 o'clock, the deceased was working on the roof of 31, Threadneedle Street. Whilst in the act of throwing a line to the opposite house he was blown off the roof by a terrific gust of wind, and fell a distance of between 50 and 60 feet. He was picked up and conveyed to the hospital, but died before he arrived there. He was quite sober at the time. "Accidental death" was the verdict of the jury.

THE PRACTICAL REQUIREMENTS OF SMALL MOTORS.*

By S. S. WHEELER.

IT is a remarkable fact that not only have none of the small electric motors thus far put upon the market been constructed on the same principles as those of an efficient dynamo machine, but no attempts seem to have ever been made to copy large machines in the very features which are known to make them efficient and practically serviceable.

Any electrician, in looking at the motors heretofore offered to the public, can see at a glance why they cannot have a good efficiency, why their resistances are necessarily high, why they have to be run at too high a speed, or why their commutators will spark badly and quickly wear out, and why it is entirely out of the question to use them for giving power in thousands of cases. And yet, notwithstanding that these objections are almost entirely removed in large motors built exactly like large dynamos, no small motors have ever been manufactured before which are any approximation to the larger machines in these important respects.

Probably the most important reason why so little attention or electrical ingenuity has been given to the subject of small motors is that the energies and inventive faculties of electricians have for the past three or four years been devoted to the problems of the transmission of large amounts of power, and especially the propulsion of street cars, &c., which present great difficulties, but difficulties that electric motors are especially suited to overcome. The natural result of this prospective demand for such sizes and kinds of electric motors as this work will require, has been the diversion of the best electrical talent in this direction, and the consequence has been the production of such machines, almost perfectly adapted to the requirements.

Meanwhile the subject of small motors has lain comparatively unnoticed. Each isolated want is of less importance to the user and of less value to the dealer than in the case of a large motor; in other words, as the small motor to be successful must be cheap, and the power to be supplied is small, there is little money in each individual case, and it is only when the number of individual users gets to be large that the matter of small motors becomes a promising field. It does not follow, however, from the lack of attention bestowed upon the subject, that there is no field for such work; on the contrary, there is an enormous number of individual instances where an electric motor would certainly be used if it was just good enough to come within the requirements.

In addition to the ordinary uses where we regard a motor as simply the best means of obtaining power for a certain purpose, for example the running of a large number of small machines in a factory, where the motors and feeding wire take the place of shafting and belts, there are many places where the work would not be practicable without one, and where a motor therefore would be said to create the use. Such are all uses of very small amounts of power where an engine cannot be run, and which are beyond the capacity of a man at a treadle. There is a large class of uses for power where a steam engine is not admissible, and where a good motor on a circuit is the only alternative, and in the absence of a motor good enough to be safe on an electric light circuit, or efficient enough to be run economically, all these industries have to be conducted in other ways, to avoid the question of small power distribution.

The response to the demand for electricity for lighting, &c., has been the production of dynamos of ninety-five per cent. efficiency, a far better result than is obtained in steam engines, and conversely these dynamos can be used as motors with the same efficiency. But the result of the needs of electric lighting, in response to which demand these dynamos have been created, is that they are machines of large power, and so in these we have motors of large power without further change, save as to means of regulation.

Now why is it that we have not already had for some years motors of very small power, and reasonably near the same perfection of efficiency?

It is because a small motor while requiring the electrical construction and efficiency-giving features of a large dynamo to be equally efficient, cannot, for several reasons, be made an exact miniature of the large dynamo in mechanical construction.

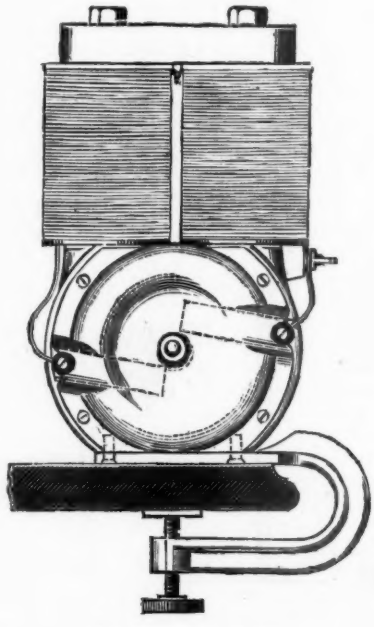
If you want a 1,000 horse-power engine, you will get a Corliss engine, with elaborate valves, adjustments, &c. But if you want one of one horse-power, you will not get a miniature of the Corliss engine, requiring an engineer to take care of it. You will get a Baxter or an oscillating cylinder engine, with no external valve gear or adjustment, which will almost take care of itself. You must to make a small motor successful for such practical purposes as it is to be used for, reduce the complication of its parts and its liability to get out of order.

Of course this is realised by every one who has given the subject any consideration, but, nevertheless, the practical result has been that the only small motors thus far produced have been made apparently without any analysis of the difficulties to be met and any consideration of the means for overcoming them. Many of these motors have been so entirely unsatisfactory that they have been looked upon as little better than toys, and have reacted discouragingly upon the public.

Some of these motors, if placed on an incandescent circuit, for which they are intended, will burn themselves up. Others are of such very low efficiency compared with dynamos, that they require treble and quadruple the amount of current to give the necessary power. This is the principal reason why small motors, run from batteries, have not been more successful heretofore. The batteries have not been particularly bad, but the motors, instead of making good use of the current furnished, which is costly at best, have simply slaughtered the battery when pressed to do the work, by drawing four times the amount of current which would do the work, if efficiently used. I refer, of course, to the failure of the motor to give a counter E.M.F. when running, to which is due this inefficiency. The E.M.F. generated by a machine when driven as a dynamo, is the real test of its efficiency.

In order to get counter E.M.F. or magnetic effect, which is the same thing, and which is shown by running the motor as a dynamo and observing how much current it will *generate*, it is necessary to have a strong field, a large number of convolutions on armature, and high circumferential speed, all of which are interchangeable as factors; while at the same time the resistance of the wire and the speed of the armature must be kept down. The first is necessary so as to permit strong current effects to be produced and large power to be exerted when the motor is running slowly, as well as to reduce the loss from the internal resistance of the machine; and the second, to avoid high working speed, which is always undesirable, for mechanical reasons. It will be observed that all of these requirements tend to the enlargement of the machine, especially of the armature.

These considerations lead to the conclusion that it is better to make the armature a little larger proportionally than it is made in large machines, in order that our very small motor may still have the proper amount of wire, &c., in the armature, and be a true dynamo, capable of giving a proper E.M.F., instead of being a mere electro-magnetic engine. By so doing, we also make the armature much easier to manufacture.



THE C. AND C. MOTOR.

There is now before the public a small motor, of which we have some specimens here to-night, in which the armature is enlarged radially, somewhat out of the usual proportion of armature to field, whereby the comparative strength of the field is perhaps reduced a little; but the armature capacity is increased in a much greater ratio, and consequently the E.M.F., or magnetic pull of the machine is large, and the internal resistance as well as the shaft speed are small.

In addition to this departure from the usual proportion in order to meet the difficulties of small motors, there are a great many special features to increase the convenience as well as the efficiency of the machine.

As I believe this motor to be the first one on the market giving an efficiency corresponding to large dynamos, and at a price proportionate within 25 per cent. of the established prices for large machines, I think a description of it will be of interest. (I may say here that later on some tests will be shown, and an opportunity will be given of examining the motors and apparatus.)

The field magnets (see the accompanying illustration) are of the simple horseshoe shape, and the armature is a Gramme armature of comparatively large diameter and short length. The Gramme ring gives room for a large number of windings, with

* Read before the American Institute of Electrical Engineers, February 8th, 1887.

small mass of iron to be magnetised, and the large diameter, compared with the length, gives greater circumferential speed, with the same windings and mass. The cores of the field magnets are of best wrought-iron, $1\frac{3}{4}$ inches in diameter and 3 inches long. The yoke and pole-pieces are of equal section with the core, as is also the armature core, thus forming a magnetic circuit all around the horseshoe and across the armature, of uniform conductivity. The yoke and ends of the cores are cut clean by machinery, and firmly bolted together, and the iron fibre of the pole piece continues up into the core, both being in one piece and of equal section. The non-magnetic base-plate extends around underneath, and forms a clamp for fastening the whole motor firmly to the edge of a table, a point of great convenience.

The armature is built up of about 40 semicircles of thin sheet-iron, riveted together with two long rivets, into a solid ring hinged on one rivet, so as to open on the opposite side to receive the winding. These thin laminæ of soft iron are separated by tissue paper, to prevent the generation of Foucault currents, precisely as it is done in the largest and most efficient dynamos. The complete armature winding, previously formed by automatic machinery, is slipped on to this split-ring, which is then closed, the open ends of the half circles fitting into each other when brought together, forming a mortised joint, which is then secured by driving a final pin or rivet through them. When this hinged ring is closed, the core forms a hollow cylinder 3 inches in diameter, $\frac{5}{16}$th inch thick, and 2 inches long.

The armature winding consists of a flat wire or ribbon, wound on edge into a single helix, the full length of which equals the circumference of the armature. The commutator, which is of the disc type, consists of 17 copper sectors riveted to a fibre washer. The latter is attached to a cylindrical wooden block which is turned true with the shaft of the motor, and to a tight fit for the inside of the ring, after the winding has been slipped on it. This block and shaft are then forced into the centre of the ring, until the outer extremities of the commutator sectors are brought within about $\frac{1}{4}$th inch of the winding on the ring. The claw-shaped outer tails of the sectors are then bent together, pinching tightly certain loops of the armature helix, which project out farther than the main body, for this purpose.

These high convolutions or loops are then soldered to the commutator strips, making a solid and extremely simple and reliable connection.

The armature shaft is mounted in bearings, which are screwed to both sides of the pole pieces. The brushes are each held by a single screw, which also makes the connection with the leading wire, and, with the co-operation of the bearing plates, holds the brush at the proper inclination. The armature of this motor has room enough for a winding, such as described, composed of 204 convolutions, and of sufficient conductivity to carry 20 ampères, half of the current passing around each side of the armature. Therefore we may say that the magnetising capacity of the armature winding is 2,000 ampère turns. Of course, the size of the wire in the armature may be changed to suit the circuit, so as to give a higher E.M.F. and less ampères, and still utilise the same amount of volt-ampères within this limit. Thus we may substitute for the 204 turns on the armature, 408 turns of wire of half the size, and still get the 2,000 ampère turns, when used on a 10-ampère circuit. The field is wound so as to carry the same current. The company is at present winding its motors with three styles of windings; the style designated A is adapted to be used on 20-ampère circuits, such as the United States Company's arc light circuits; another style, designated type E, is wound for 10-ampère circuits, such as the Brush arc circuits; and the third style, designated L, is wound for 100-volt circuits or thereabouts, such as the Edison incandescent circuits.

In regard to the power and efficiency of these motors, I have found that when running at 1,500 revolutions per minute, a moderate speed for motors of this size, and, therefore, taken as the basis of tests, the 20 ampère motor, or type A, with 20 ampères passing through it, shows a difference of potential across its binding posts of 7 volts, 5 volts due to counter E.M.F., and 2 volts due to resistance. This means 150 volt-ampères consumed in the motor, or a little more than one-sixth of an electrical horse-power. Under these conditions a Prony brake shows a pull of five ounces on a one-foot lever; that is two foot-pounds per revolution, or about one-tenth actual horse-power at 1,500 revolutions per minute. The windings for other circuits give results to correspond. Therefore, when the motor is running with all the current it can carry, it uses about one-seventh horse-power of electrical energy and gives about one-tenth horse-power of useful power, or 50 per cent. of the energy used, allowing for slight additional losses, which is about double the efficiency of any small motor which I have examined. And this performance is with a current heavier than can be carried by other motors. When running with about three-fourths of this amount of current, or about 15 ampères, the efficiency is considerably greater, reaching about 60 per cent. This is the best working load for the motor, because the loss by the resistance of the machine is less. But when we get down to about 7 or 8 ampères we find that the efficiency falls again, owing to the approach to the limit of weakness in the field. And when we reach 4 ampères, we find there is just field-magnetism enough to turn the machine.

The loss of this initial current of 4 ampères in charging the field is unavoidable, on account of the necessity of having enough mass of iron in the field to use the full two thousand ampère turns that the motor has, when fully charged, without bringing the iron too near the point of saturation, or, in other words, to make the motor large enough to use $\frac{1}{4}$ H.P. of current, without passing the point of saturation. Hence we see that if a motor is intended for use with a small current, it is better to make the field magnets of smaller diameter. This is another illustration of the difficulties to be met in making motors which will be good under varying loads.

In regard to its use as a generator, the motor with 20-ampère winding will give about 5 volts when running at about 1,500 revolutions per minute, and as its current capacity is 20 ampères, this means, allowing $\frac{1}{4}$ volt lost by resistance, 90 watts, or about $\frac{1}{8}$ H.P. of electrical energy in the external circuit. That is, enough to light a 16 candle-power lamp. By changing the size of wire and putting on sufficient convolutions to get a high E.M.F., we get a generated current of 1 ampère and 90 volts, sufficient for a 16 candle-light, with a consumption of $\frac{1}{4}$ actual H.P.

As the motor was originally designed for domestic use in running sewing machines with a battery, the current from which is necessarily very expensive, great stress was laid upon designing it so as to make the very best possible use of the current, for the sake of economical running, and also to make the motor as small and light as possible with the capacity required.

This latter consideration led to the immediate determination to use the very best wrought iron, and it is only by making these necessary elements of good construction the first consideration in their manufacture, that a motor of this surprising efficiency has been produced.

In proof of the correct design and success of these motors, it may be interesting to hear that the semi-automatic machinery which was originally made for their manufacture has been kept in operation continuously for the last three months without interruption, and that already over six hundred of the motors are in use.

Discussion.

Mr. P. Diehl: I have made experiments on electric motors, and have succeeded in making various types. One of these I have placed on the market; but since then I have made quite a number of improvements. I have finally come to the conclusion that the armature to be put in this motor should have more sections. The one which I have been making has only four sections, and the sparking is considerable at the commutator, but I have lately produced various motors, especially one to run sewing machines, by placing the motor directly within the sewing machine—that is, putting the motor entirely within the sewing machine wheel, so that nothing can be seen of it. It is on the end of the shaft, directly connected without any belting. There is a great gain in that, as you can do away with the friction of belting, which is considerable on a small motor. In those motors which I produced before, the armatures were too small. I have found that the armatures have to be enlarged. I have built armatures on the Gramme type, and I found for a small motor about three inches to be the best size. I have made armatures in sections, of two halves, which are of easy winding; but otherwise the field is about the same as the one I previously made. The motor I intend for a sewing-machine exclusively is entirely in the wheel of the machine. It is a Gramme ring, made in two sections and held inside in the wheel. It is held in position by screws, so that it can be centralised. I have a field magnet in the inside of the ring, which gives me very good satisfaction. The wheel and motor together weigh about five pounds. The wheel is only the housing for the motor. For fans and for such purposes I have built it in a different shape, but I use also the Gramme ring. I have come to the conclusion that it is a better shape than the T armature.

Mr. G. W. Mansfield: I certainly would speak most heartily in commendation of the ingenious methods which the C. and C. Company have adopted and devised for overcoming some of the most difficult mechanical questions which existed in the early constructions of the small motor. I do not know but that the main reason why the Gramme ring was not used for small motors at an earlier date was the fact that the armatures could not be wound cheap enough to answer the purpose. They had to thread the wire in through this little ring and out again by hand, and the method adopted by the C. and C. Company has certainly overcome that difficulty in a very nice way. I think that in overcoming that difficulty they have started in on a sound theory, that small motors can be built just as efficiently as large motors, and there is no reason, hardly, why they should not. Of course, if the analogy can be carried out, we all know that small steam engines cannot be built to operate as efficiently as large steam engines.

Mr. Wing: I would prefer to listen a little longer and to ask a few questions before undertaking to address the meeting at length One of them is the question of batteries, primary or secondary, or any other kind. Are any here prepared to answer as to any of the existing batteries being practicable for long periods of time, so that the purchaser of a small motor can afford to run it? I have investigated quite a number, and, so far, none of them have proved satisfactory. I would limit the question to three horse-power; one horse-power will do. If I sell a sewing-machine, or a fan, or a lathe, or anything else, I want to know commercially how long I can guarantee that battery to run and how much it will cost to run it per day, per week, or per month.

Mr. Wheeler: I might perhaps give you some figures about the batteries we are making; but I think on points of exact science, about the cost of running them, &c., I could refer you to Mr.

Crocker, who is one of the mechanical experts of the company, and who has more figures in his head than I have. I might say, however, that our battery is an electro-poion battery, having no porous cup. Instead of using carbon plates we use pencils. We use the regular electro-poion fluid, except that it is a solid. Here (exhibiting) is some of the material, and if we add pure water to that and analyse the solution, we will get almost exactly what electrical dealers call electro-poion fluid. We do not have to use jars any larger than you would in a Bunsen battery. The amount of chemical energy in this solution is just the same as it is in the same volume of the ordinary electro-poion fluid.

Mr. WING: I have found this difficulty in all those with which I have experimented, that when you come to take them commercially, there is the inconvenience of emptying the jars and replacing them.

Mr. WHEELER: It is giving that point due consideration which has led this company to produce a battery jar, which has a very suspicious appearance (exhibiting a porcelain jar provided with a handle. Laughter). As that has got about a tenth of a horse-power in it, I do not want to upset it.

Mr. MAILLOUX: How many sewing machine hours has it got?

Mr. WHEELER: It has got about six sewing machine hours. The electromotive force is $3\frac{5}{10}$ volts; the internal resistance is about $\frac{8}{100}$ of an ohm. When you begin to use it, it rises up to about $\frac{15}{100}$ of an ohm when the solution is mixed up with the acids of the reaction. The resistance is, therefore, higher, so that the fair average is about $\frac{1}{10}$ ohm internal resistance, and the capacity of the battery is 12 ampères. It will keep on furnishing 12 ampères without declining until the chemicals are all used up. If you short-circuit the battery it will give more ampères than any battery that I know of. I have got one that will measure up to 45 ampères, and it will give even more ampères than that. It will give about 50 ampères on a short circuit. Of course it will not keep that up more than three or four minutes, because the solution will not circulate fast enough to bring fresh material up to the zinc in time. It will stand 20 ampères for five or ten minutes, but it will easily stand 10 ampères continually. It does not furnish 12 ampères to run a sewing machine for six hours because a motor, when running a sewing machine, will use only about $8\frac{1}{2}$ ampères. Of course, the resistance of the motor will allow about twice that amount to flow. It takes two of these jars to run a motor at a lively rate; one will run it.

Mr. WING: Suppose you want to run five or six hours during the day and eight or ten hours at night, how many cells would it be necessary to have and how long would those cells last without replenishing? I do not mean to get right down to the hour.

Mr. WHEELER: Do you mean continuous running? You know if you give the machine to a person he will say that he uses it continuously. The facts are that they sew for a minute; then they stop to shift the direction of their seam, &c., and the battery is not drawn upon. I have to make that distinction, because an absolutely continuous run is a very different thing from a "human being run," so to speak.

Mr. WING: I am getting at the actual run, four hours during the day and an eight-hour run at night.

Mr. WHEELER: I think you would have to have jars of about twice the size of this. Of course, if you were not going to do the work at any greater rate than this, you could use the same solution and simply have larger jars. If I were going to do it, I should have another pair of jars ready and slip them in when the first were exhausted. It is only a question of having enough solution there to keep it up for that length of time.

Mr. WING: My experience is that I cannot sell a machine to run by jars in the ordinary form, for the simple reason that they have to change them too often and it is too much work to change them. In running a sewing machine, as Mr. Wheeler observes, they run a minute and then they do not run a minute, and sometimes do not run for ten minutes; but when you come to put this same motor upon a fan or lathe or machine that requires continuous running, the fan is probably the worst thing you can put on to a motor, because it is a dead pull from the time you start it. Now, we sell fans largely for that purpose, and they want to be run about four or five hours for office business. Many thousands could be sold for ventilation of private residences, sleeping rooms and the like, if we could get a battery, or if we could get the power at a moderate price to run those motors during the sleeping hours, say eight or ten hours, but it must be a steady run.

Mr. PENDLETON: I think if the circuit were established from central stations, there would be no difficulty in running either a fan or a sewing machine satisfactorily. At the present time you are obliged to do what you can with the best batteries in existence at the present day.

Mr. CURTIS: I think the kind of fans Mr. Wing refers to chiefly are fans that require more than half a horse-power to drive them.

Mr. WING: No, sir; a thousand could be sold for that purpose at about one-eighth to one-fourth horse-power, for sleeping rooms. This motor has got the power for that purpose, as I can see from the speed at which it runs the fan here. One eighth or one-fourth of a horse-power will do very well for sleeping room purposes, and thousands will be sold for that alone.

Mr. CURTIS: The power of one of these batteries is about $\frac{1}{20}$ to $\frac{1}{30}$ of a horse-power. Now if you want $\frac{1}{10}$ of a horse-power you would require four to six of these batteries. A tenth of a horse-power on a small motor is a good deal more than you would expect. When we were running it here, we were running from the Edison circuit and we were taking about as much current as one of these lamps takes. We were taking a little more, a tenth of a horse-power.

Mr. WING: A tenth of a horse-power is ample for the purpose I referred to.

Mr. CURTIS: The question is whether somewhat less than a tenth would be enough.

Mr. WING: It would be for smaller rooms.

Mr. CURTIS: When we took up the problem we found that there was not any battery in the market which, unless we used a good many cells, would give anything like the necessary current. Now the only way to get the power out of that is by fulfilling two conditions. In the first place you have got to have large plates so that you do not draw a heavy current over a small surface. In addition to that you have a very low resistance. As soon as the resistance of your batteries comes up, you have got to add cells. The resistance of the two cells is only $\frac{1}{20}$ of an ohm, which is ridiculously low for a battery of that size. There is not any battery made to-day which is as low as $\frac{1}{20}$ of an ohm for one cell except a very large plunge battery. Now the only battery which would take the place of this that could be used to give the same volts and ampères before we got this up was something like a Bunsen battery or an ordinary plunge battery. The difficulty with the plunge battery was that it would not maintain a current; there was no circulation of the liquid; and then if we put the plates nearer together the circulation would form the sulphate of zinc on one plate and form the water on the other plate and we could not maintain the action, and you had to stop and give it a rest and then start off again.

Mr. WING: That has been my experience in all that I have tested.

Mr. CURTIS: That is eminently the case in any form of battery where provision is not expressly made for circulation. In this battery we can get from about a square inch of surface about an ampère. You take a battery with a porous cell in it, or an ordinary plunge battery, and it will have perhaps 12 square inches to the half ampère. This battery will give from five to 10 times as strong a current for a given area of zinc as any battery I know of. We seem to have got as near the limit of lowness of resistance as possible, because unless you can lower the specific resistance of the solution, you cannot bring your plates any nearer; there is nothing intervening which you can take out and you have got the resistance as low as you can get it.

The only way in which you can get power enough out of this kind of battery to give you one-tenth of a horse-power is by adding cells or making larger cells. Now, you can do that easily enough. But nevertheless it involves having the cells four times as large or having four times as many of them. Then the domestic conditions come in; perhaps you can use it, perhaps you cannot. There is not any battery at all that it is worth while to talk about for a half horse-power, entirely irrespective of the cost of solution. The solution is quite a costly thing anyway. The cell we employ will give a fortieth of a horse-power continuously for, say six hours. That costs one charge of solution, and one charge of solution costs about 30 cents. So it costs 30 cents for six hours. There is no difficulty in obtaining all the power you want if the electric light circuits are there. We anticipate that all cities are going to have arc or incandescent circuits for domestic use, and we propose to put our motors on those circuits. You can put one of these motors in the place of one of these lamps here, as we do now, and it will give you a tenth of a horse-power.

Mr. WING: Do you intend to build your motors for arc circuits?

Mr. CURTIS: Yes; we have some already built. They are boxed up to protect them, that is, to protect the people outside of them from touching them and getting a shock.

Mr. WING: Do you have to have any resistance coils?

Mr. CURTIS: We have a shunt which controls them. They have a multiple arc with a variable resistance.

Mr. WING: I have understood that you have already put some on the Brush circuit. Have you arranged with them as to charges?

Mr. CURTIS: In some of the cities we have. We have not arranged in New York yet. The Brush people are trying it now. Mr. McGrath, who is superintendent of the district in New York is trying it for his own station. I believe he says that they are just what they want for their circuits.

Mr. WHEELER: Mr. McGrath reports 45 per cent. efficiency on his circuits with this motor.

Mr. WING: He told me they were prepared any time they got a motor that was satisfactory to them to put it in. I understand that in Baltimore the Brush people have agreed to furnish the Baxter motor with a horse-power at $5 a month. They are doing it right along all the time, for one horse-power or 10 little ones at the same rate. They are putting them in a great many places where they are using sewing machines.

Mr. MARTIN: In Philadelphia the Brush Company are running about 200 small motors on their arc circuits.

Mr. MAILLOUX: I had recently occasion to experiment with various forms of batteries while conducting some researches with the new exciting liquid which has come into the market lately under the name of "coquimbite," and while experimenting with it, I had occasion to use some batteries which are made in Philadelphia by Partz, called the Partz acid gravity battery. It is a square cell in which the carbon is placed on the bottom. The carbon has a corrugated surface. He has one form which is simply a zinc, as in the gravity cell. In the other form, he has a porous cup with the zinc inside, and I have found that when the liquid was at the lowest specific resistance possible, the total resistance of the cell, carefully measured, was as low as $\frac{1}{100}$ ohm, and con-

sequently anybody might think that you might obtain a very large volume of current; but unfortunately as soon as you close the circuit you find that there is only a very small current, comparatively speaking. You may get between five and 10 ampères; but even that not for a great length of time, simply because you have the counter-electromotive force of polorisation which immediately reduces the available electromotive force. I am told they are using these batteries with great success for dental purposes. They generally run them in series of three or four, and do not ask such a great rate of current of them and depend upon greater electromotive force to get the greater number of watts necessary. The cell is certainly a very convenient one, so far as construction goes, because it is so made that it will run without care and with comparatively very little attention for months. I have not carried out my experiments with the battery with the Partz solution, and consequently I cannot tell how long it will last; but it occurred to me that it was a very convenient form of cell particularly for in-door use, office work and places where the battery is to be tried for a certain length of time and where it is desired to have a battery that does not require much looking after. I succeeded in getting four ampères out of a coquimbite solution, and I was led to reason from that that possibly the other would give a higher current, and I think that some party I have met told me that Mr. Partz himself was using them a great deal for motors where the current continuously was from two to 10 ampères.

Mr. CURTIS: Dr. Partz tried it in my office and it would not maintain more than three.

Mr. MARTIN: This whole motor question resolves itself into a question of current. If once we have the motor, as we have, the question comes, where shall we derive the current to drive it? It is very apparent, I think, from this discussion, that the day of the primary battery in driving motors is not a very long one. Where shall we get the current then? We can get it largely from the arc circuits; we can get it from the incandescent circuits. There are 700 to 1,000 motors on arc circuits, and a great many on incandescent circuits. Mr. Sprague, for instance, has a large number of small motors in Boston, 25 or 30 at least running on the Edison three-wire system. But in order to put motors into residences and have them running when people want them, you want to have a current that is available all day long in a great variety of places. Hence, to get that current, it seems to me we must in the last resort fall back on the secondary battery.

Mr. MAILLOUX: There are very many features about small motors worthy of a great deal of attention; one is the efficiency of small motors. We have all been educated somewhat to look at the efficiency of a small motor as being necessarily low, but that is simply because we have not learned to dissociate the various factors of efficiency. We must first determine what we mean by efficiency, whether we shall indicate by that term the absolute efficiency of the machine or merely its efficiency to convert mechanical energy into electrical energy, or *vice versâ*. The point I wish to emphasise particularly is this: That while a motor may be very small and have a very small mechanical efficiency, a small co-efficient of conversion, that is to say, its power to convert electrical energy into mechanical energy, may be comparatively small when compared to a machine of much larger dimensions, yet the total efficiency may still remain at quite a respectable figure. That is, that when used as a generator it would convert a small proportion of energy of one kind into energy of another; but the total efficiency is not affected by that; it is the product of the electrical efficiency in the circuit and the efficiency of the machine itself. Consequently, if your motor efficiency is lower then you have only to raise the electrical efficiency in order to have still a total efficiency which shall be equal in any case. In saying this, I have reference more particularly to tests made by various authorities, such as Ayrton and Perry, Prof. Anthony and Lieut. Duncan, and others, in which they have shown very low total efficiency for small motors. I think in some cases as low as 13 per cent. of the total energy, and in no case above 50 per cent. was shown. Now I have believed that they were not giving the motor a fair show. The instrument from the necessary complications and limitations of its construction, it being of a small size, would be a very poor instrument to convert energy, so that its own co-efficient of conversion would be very low. Yet, although its efficiency may be very low, the efficiency of the circuit is entirely independent, and that is the ratio of the total amount of work being done. It is a function of the total amount of work that is being done in any case. In any electrical circuit the efficiency of energy transmitted varies as the counter electromotive force. It is a ratio of the counter electromotive force to the total electromotive force. Let us suppose, that this machine when used will transform 80 per cent. of the mechanical energy applied to it into electrical energy. Let us suppose, further, that 90 per cent. or 95 per cent. of that will be useful in the external circuit; so we have a total co-efficient of useful conversion of ·80 times ·95, which is 76 per cent. Now that is the coefficient of conversion so far as useful effect is concerned. Then let us suppose that we have a battery so arranged that it will allow this motor to run at as high a speed as possible, and that we get the power out of it when it is running at 1,500 revolutions. Let us suppose that the current is as small as is consistent with getting the power.

Mr. CURTIS: Excuse me. It is the resistance of the motor that determines that thing.

Mr. MAILLOUX: Not necessarily.

Mr. CURTIS: You are running your counter up just as near your direct as you can. Now it is that resistance that determines the amount of current.

Mr. MAILLOUX: No; it is the total electromotive force you are using in the first place. If you are using a large total electromotive force, then your motor can give a higher electromotive force; consequently it will develop a larger counter-electromotive force, and the ratio of the two would be large. Now, the total work that will be given to that motor may be anything you please. Let us take the case of the Edison circuit. This machine can be wound so as to give comparatively a high counter-electromotive force, and we can make the ratio as high as we please and get the same power with a much lower current, and I find he uses a current of $\frac{5}{10}$ ampère. Now this would show that the counter-electromotive force of the instrument would be a higher ratio, and we may easily see that you cannot get 90 per cent. electrical efficiency. In other words, the amount of the electrical energy that is required to transform the energy of the moving part in proportion to the amount that is absorbed in it is the ratio of counter-electromotive force. Therefore the electrical efficiency will be anything you please, according to the speed with which the motor is run. Therefore the total efficiency will be ·76 times ·90, which is a little over 60 per cent. That is what I mean to say—that although this may have a very low conversion, yet by raising its electrical efficiency we can raise the commercial efficiency.

Mr. CURTIS: What is called commercial efficiency is the same thing as what you mean, taking into account the external and internal resistance in the machine. Take an ordinary dynamo machine; it does not affect the converting power, whether it has a high internal resistance or a low internal resistance. In regard to the amount of current that it is necessary to supply it with in order to obtain a given power, that element is of no importance at all; nobody cares what the internal resistance is. The only trouble about having high internal resistance is that it absorbs the power, and then it prevents self-regulation. There is a great deal of talk about commercial efficiency. The most important thing is just the converting power. If you put 100 volts and $\frac{5}{10}$ ampère on that wire, then put on the friction brake and take out the foot pounds, the proportion of friction that goes out to the ampères that go in gives the important thing as regards efficiency. The other important thing is how many dollars worth of ampères it takes to give an eighth of a horse-power, or a tenth of a horse-power, or two horse-power, whatever you want.

Mr. WETZLER: I rise to a point regarding the efficiency, not theoretical, but in a practical sense. I would like to call attention to a fact in regard to the construction of the armature of a motor. I am acquainted with a very well known electrician who had started out to make a small motor of large efficiency, one which should approach the efficiency of the larger motors. He started out with a solid armature of the Siemens type. He got, I believe, 15 or 20 per cent. He tried all sorts of winding, &c., It occurred to him that it might be well to laminate that armature, which he did to a certain extent, and he obtained 10 to 20 per cent. more efficiency. He kept on increasing the number of his laminations until he reached 60 per cent. Consequently, I would like to point out that the efficiency of a small motor must be looked for to a considerable extent in the lamination of the armature. I see in the armature before me that the attempt has been made; but it strikes me that it could be improved upon, if the suggestion is allowable. It seems to me that there may be some chance of the current getting across these sections.

Mr. CURTIS: We made one test. We mounted one of those rings on a wooden block, without any winding on the armature, and ran it at a high speed, and we found that whether you turned the field on and off or not, that is, whether it was revolving in the magnetic field or not, made only a very small difference, and was that with an armature in which the laminations were only half as thin as they are there.

Mr. WETZLER: You had no windings on that at all.

Mr. CURTIS: No windings.

Mr. WETZLER: You cannot say, then, that the conditions were exactly alike. Did you ever try a solid core with your actual windings on it? That would be a crucial test.

Mr. CURTIS: No; that would be so vastly different from a solid core. Until you get up to a certain point the efficiency runs up very rapidly. Beyond that point the Foucault currents are so small that it does not pay to carry them much further. We considered the thing very carefully, and I do not believe that there is over 5 per cent. lost at the very outside, by Foucault currents.

Mr. WETZLER: You will also remember that some time ago Mr. Mordey pointed out distinctly that the loss in the motors was due to that very cause, the Foucault currents. There is another point I want to bring up, and that is, do not you, gentlemen, consider it advisable to have some arrangement for reversing the motor? For many applications it is desirable that the motor should run in the opposite direction.

Mr. WHEELER: Do you mean momentary reversal?

Mr. WETZLER: To run a machine in either direction.

Mr. WHEELER: You can do that; you can change the field connection for one thing.

Mr. WETZLER: I mean to have your motor on your lathe or work-table, and be able to turn a switch or any other mechanism and have the motor run in the opposite direction.

Mr. CURTIS: We have not had any demand yet for such a machine, and the principal purpose that has occurred to us for that kind of thing is for use on a boat.

Mr. WETZLER: I can see very well that there would be more than one application for that kind of motor. For instance, a dental lathe would want to be reversed.

Mr. MARTIN: I have had dentists ask me if I knew a motor of that type.

Mr. CURTIS: One point about these brushes is that they are arranged so that the armature can be turned in either direction without destroying the brush.

Mr. PENDLETON: I had some years ago a surgeon of this city making some experiments with an osteotome in my laboratory for the purpose of testing the power to be received from an accumulator, and for that purpose he brought down with him tibiæ, feet-bones and so forth, and had his little saw attached to his surgical instrument which operated very satisfactorily; at least he said that he had never been able to get such results from any primary battery, and he had spent several thousand dollars in trying to perfect a system suitable for his purposes. I noticed that his instrument got upon a dead point several times and I asked him how it was. He said it was the best he could find. I then furnished him with a motor which has attracted some little attention, although it has never been put on the market to any extent. I have received letters from Paris in regard to the cut of it which was published by the *Electrical World* some time ago. That little motor fulfilled its purpose, and it was simply the commutation of two brushes upon a three-pole armature with the usual circuit, so that there was a continuous current through the two circuits of the armature, and the polarities gave on the three-pole armature all the attraction and repulsion that was capable of being derived. I finally conceived that it would be a benefit to use discs of thin iron, and my experience in the matter fully coincides with the remarks made here to-night. There was an efficiency of at least 25 per cent. merely from replacing the cast iron by the wrought iron. In regard to the loss by Foucault currents mentioned, this ring travelling in the periphery of the armature would not suffer from Foucault currents as much as the ordinary armature which is placed directly upon the shaft, and having the speed of the periphery so much higher than the iron nearer the shaft. In that respect I should hardly think that 65 per cent. would be an over-estimate, whereas in the ordinary H armatures it would be much greater. In regard to insulation, an insulation by peroxydising this iron might be sufficient, instead of taking up the space with paper. These little motors are now becoming very interesting, and their importance will be appreciated so soon as we can get the current to introduce them generally, and when the time comes do not forget that the secondary battery will be a most valuable apparatus to regulate and govern these motors, and economise at the same time the power which would be lost in any other method of governing.

NOTE ON THE THEORY OF THE ALTERNATE CURRENT DYNAMO.

By JOHN HOPKINSON, M.A., D.Sc., F.R.S.*

ACCORDING to the accepted theory of the alternate current dynamo, the equation of the electric current in the armature is $\gamma \dot{y} + R y =$ periodic function of t, where γ is a constant coefficient of self-induction. This equation is not strictly true, inasmuch as γ is not in general constant,† but it is a most useful approximation. My present purpose is to indicate how the values of γ and of the periodic function representing the electromotive force can be calculated in a machine of given configuration.

To fix ideas, we will suppose the machine considered to have its magnet cores arranged parallel to the axis of rotation, that the cores are of uniform section, also that the armature bobbins have iron cores, so that we regard all the lines of induction as passing either through an armature coil, or else between adjacent poles entirely outside the armature. The sketch shows a development of the machine considered. The iron is supposed to be so arranged that the currents induced therein may be neglected. We further suppose for simplicity that the line integral of magnetic force within the armature core may be neglected.

Let A_1 be the effective area of the space between the pole piece and armature core when the cores are in line, l_1 the distance from iron to iron.

Let A_2 be the section of magnet core, l_2 the effective length of a pair of magnet limbs, so that l_2 may be regarded as the length of the lines of force as measured from one pole face to the next.

Let m be the number of convolutions in a pair of magnet limbs, and

n, the convolutions in one armature section.

T the periodic time.

The time is measured from an epoch when the armature coil we shall consider is in a symmetrical position in a field which we shall regard as positive.

x and y are the currents in the magnet and armature coils, the positive direction being that which produces the positive field at time zero.

At time t the armature coil considered has area A_1',

$$= b_0 + b_1 \cos(2\pi t/T) + b_2 \cos(4\pi t/T) + \&c.$$

in a positive field, and area A_1''

$$= b_0 - b_1 \cos(2\pi t/T) + b_1 \cos(4\pi t/T) - \&c.$$

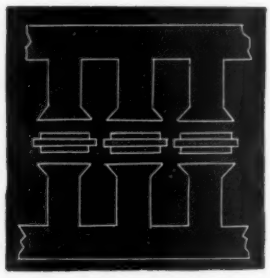
in a negative field, where

$$b_0 + b_1 + b_2 + \ldots = A_1,$$

and

$$b_0 - b_1 + b_2 + \ldots = 0.$$

The coefficients b_0, b_1, &c., are deducible by Fourier's theorem from a drawing of the machine under consideration.



Let I be the total induction in the magnet core, and let at time t I be distributed into I' through A_1', I'' through A_1'', and I''' as a waste field to the neighbouring poles.

The line integral of magnetic force from the pole to either adjacent pole is I'''/k where k is a constant.

We have first to determine I', I'', I''', in terms of x and y.

Take the line integral of magnetic force in three ways through the magnets, and respectively through area A_1', through area A_1'', and across between the adjacent poles—

$$l_2 f\left(\frac{I}{A_2}\right) + 2 l_1 \frac{I'}{A_1'} = 4\pi m x + 4\pi n y,$$

$$l_2 f\left(\frac{I}{A_2}\right) + 2 l_1 \frac{I''}{A_1''} = 4\pi m x - 4\pi n y,$$

$$l_2 f\left(\frac{I}{A_2}\right) + \frac{I'''}{k} = 4\pi m x,$$

whence $I' + I'' + I''' = I$

$$= \left(\frac{A_1' + A_1''}{2 l_1} + k\right)\left(4\pi m x - l_2 f\left(\frac{I}{A_2}\right)\right) + \frac{A_1' - A_1''}{2 l_1} 4\pi n y,$$

when t, x, and y are given, this would suffice to determine I by means of the known properties of the material of the magnets as represented by the function f. We will, however, consider two extreme cases between which other cases will lie.

First.—Suppose that the intensity of induction in the magnet cores is small, so that $l_2 f(I/A_2)$ may be neglected, the iron being very far from saturation. We have—

$$I' - I'' = \frac{4\pi}{2 l_1}\left\{m (A_1' - A_1'') x + n (A_1' + A_1'') y\right\}$$

$$= \frac{4\pi}{l_1}\left\{m\left(b_1 \cos\frac{2\pi t}{T} + b_3 \cos\frac{6\pi t}{T} + \ldots\right) x + n\left(b_0 + b_2 \cos\frac{4\pi t}{T} + \ldots\right) y\right\}.$$

We see that the coefficient of self-induction γ in general contains terms in $\cos 4\pi t/T$.

Second.—In actual work it would be nearer the truth to suppose that the magnetising current x is so great that the induction I may be regarded as constant, and the quantity $l_2 f(I/A_2)$ as considerable. But as small changes in I imply very great changes in $l_2 f(I/A_2)$, its value cannot be regarded as known; we have then—

$$2 l_1 \frac{I'}{A_1'} = \frac{2 l_1}{A_1' + A_1'' + 2 k l_1}\left(I - \frac{A_1' - A_1''}{2 l_1} 4\pi m y\right) + 4\pi m y.$$

$$2 l_1 \frac{I''}{A_1''} = \frac{2 l_1}{A_1' + A_1'' + 2 k l_1}\left(I - \frac{A_1' - A_1''}{2 l_1} \cdot 4\pi m y\right) - 4\pi n y,$$

whence

$$I' - I'' = \frac{(A_1' - A_1'') I}{A_1' + A_1'' + 2 k l_1} - \left\{\frac{(A_1' - A_1'')^2}{A_1' + A_1'' + 2 k l_1} - (A_1' + A_1'')\right\}\frac{4\pi n y}{2 l_1}$$

$$= \frac{(A_1' - A_1'') I}{A_1' + A_1'' + 2 k l_1} + \frac{4 A_1' A_1'' + 2 k l_1 (A_1' + A_1'')}{A_1' + A_1'' + 2 k l_1} \cdot \frac{4\pi n y}{2 l_1}.$$

For illustration, consider the simplest possible case: let $b_0 = b_1 = \frac{1}{2} A_1$, and $b_2 = b_3 = \ldots = 0$, and let $2 k l_1$ be negligible; we have—

* Read at a meeting of the Royal Society, March 10th, 1887.

† "On the Theory of Alternating Currents," *Teleg. Engin. Jour.*, vol. 13, 1884, p. 496.

$$\iota' - \iota'' = \iota \cos \frac{2\pi t}{T} + A_1 \sin^2 \frac{2\pi t}{T} \cdot \frac{4\pi n y}{2 l_1},$$

and the equation of current will be—

$$E y = n \left\{ \frac{2\pi}{T} \iota \sin \frac{2\pi t}{T} - \frac{2\pi n A_1}{l_1} \frac{d}{dt} \left(\sin^2 \frac{2\pi t}{T} \cdot y \right) \right\},$$

instead of the simple and familiar linear equation.

ON THE VERIFICATION OF FARADAY'S LAW OF ELECTROLYSIS WITH REFERENCE TO SILVER AND COPPER.*

By W. N. SHAW, M.A.

SINCE the time of Faraday his law of electrolysis has not been subjected to any very extensive experimental investigations. A summary of the results obtained is given in the article on electrolysis in the "Encyclopædia Britannica." The most accurate verification appears to have been conducted by Soret, who attributes to the law an accuracy of 0·2 per cent. for copper and silver. Buff used different currents, and found the law verified by experiment to about 1 per cent., but the general impression has been that the law was only true to a somewhat rough approximation.

A practical acquaintance with the behaviour of an electrolytic cell of copper sulphate shows that it is not *necessary* to attribute the defect from the theoretical value of the chemical equivalent obtained in that way to the failure of Faraday's law. In depositing copper upon a copper plate it may often be observed that small but brilliant red crystals are formed on the deposit. These crystals under the microscope are very beautiful: they may probably be regarded as a suboxide of copper formed by the action of the copper on the solution. A purple colouration is, moreover, often formed on the cathode, and this is possibly due to the presence of the same compound of copper. This secondary action produces, of course, a difference in the weight of the deposit formed, and the true amount of electricity which has passed cannot be inferred either from the weight of the copper with the compound or from the weight of copper remaining when the crystals have been removed.

Further, it is well known that a copper plate when immersed in a solution of copper sulphate without any current gives rise to some chemical action which causes the copper plate to alter in weight. The alteration may be either in the direction of increase or of decrease of the weight, the effect depending upon the state of the plate and the state of the solution.

In considering the increase in weight of a copper cathode in an electrolytic cell we cannot without definite experimental reasons neglect to consider the possibility of both these actions occurring together, and, moreover, the passage of the current may produce complicated results which cannot be inferred from the action of the solution in the cell under other conditions. Dr. Gore has made very numerous experiments upon this subject, without, however, arriving at any very satisfactory result.

In view of the importance of the subject, a very large number of experiments have been made at the Cavendish Laboratory at Cambridge under my direction during the past two years. They may be divided into two groups. (A.) Experiments to ascertain whether two copper cells give the same amount of deposit for the same current; and (B) experiments to determine whether a copper cell can be arranged so that, on comparison with a silver cell, within sufficiently wide limits of current it will give a value of the chemical equivalent of copper agreeing with that obtained by chemical methods.

A.—EXPERIMENTS ON COPPER CELLS ONLY.

These experiments consisted in arranging pairs of copper cells with various electrodes, as copper plates, copper wires, copper cylinders having wire connections, platinum wires, in order to ascertain whether the disturbing actions were limited to the surface. The results were very irregular and disappointing. Errors amounting frequently to more than 1 per cent. occurred without any assignable cause.

The same is all that can be said about experiments with different solutions of sulphate, including solutions from which air had been expelled by boiling, the experiments being then conducted under the receiver of an air pump. Endeavours to allow for the differences of the cathode weighings by supplementary experiments on the effect of the solution upon plates not connected with the electrodes have likewise proved fruitless. The enumeration of these experiments would serve no practical purpose, as they lead to no generalisation; I shall therefore pass over them.

B.—EXPERIMENTS ON THE COMPARISON OF SILVER AND COPPER CELLS.

One of the most disagreeable features of the experiments referred to in the preceding section was that when two cells were compared, and a difference in the increase of weight of the cathodes was obtained, it was impossible to say whether either or both of the two cells was at fault, and it was therefore decided to employ a silver cell as a standard. Lord Rayleigh was at the time engaged on his experiments upon the absolute value of the electro-chemical equivalent of silver, and had not yet arrived at a result. Experiments were therefore made to obtain a silver cell that might be fairly regarded as a standard. The only difficulty in the way was that the deposit of silver from pure nitrate is crystalline and very rough. The deposit was taken upon a platinum crucible, and it was feared that error might arise, either from mechanical loss of the silver during the operation of drying, or from the retention by the deposit of water, or salt in solution. Attempts were therefore made to use as electrolyte (1) a solution of chloride of silver in hypo-sulphite of silver; (2) a solution of nitrate of silver containing glycerine; (3) a solution of nitrate of silver containing acetate of silver. The deposits obtained with all these are much closer and harder, but the hypo-sulphite solution is very unstable, and a current beyond a certain density precipitates a black sulphide which destroys the experiment. The other solutions were also discarded after consultation with Lord Rayleigh, who had then shown that a 15 per cent. solution of pure nitrate gave a perfectly satisfactory silver cell if proper precautions were taken with the drying, whereas the solutions containing organic salts were liable to serious error, probably in consequence of the inclusion of the solution in the pores of the deposit.

It was originally intended to use only those experiments from which the loss of the anode was obtained equal to the gain of the cathode. It was found, however, that the possibility of weighing the loss of the anode was simply fortuitous, the action of the solution upon the silver always producing a sort of honeycomb formation, and ultimately leaving smaller particles which fell off in washing. This was the case even when a silver crucible was used as the anode. It was therefore decided to use the gain of the cathode only. The form of silver cell adopted is that of Poggendorff's voltameter, in which a platinum crucible standing on a copper plate is the cathode and a silver rod the anode. The crucibles were about 1¼ inches in diameter and 2 inches high, and the silver rod forming the anode was about half an inch in diameter.

The method of drying the deposit was to wash in distilled water by filling up the crucible several times, and allowing it to stand for some time, then, after thoroughly rinsing, to wash it out with alcohol and dry in a hot air bath at about 260° C.

As the crucibles were very different in size from those used by Lord Rayleigh some experiments were made to determine their behaviour.

The following are the results:—

Comparison of Two Crucibles of Different Sizes.

Date.	Time in minutes.	Current in ampères.	Large crucible grammes	Small crucible grammes.	Difference.
Feb. 6.	100	·3096	2·0789	2·0802	−·0013
„ 7.	120	·3638	2·9312	2·9364	−·0052

Comparison of an Old and New Crucible.

			Old crucible.	New crucible.	
Feb. 11.	120	·4677	2·5203	2·5183	·0020

Comparison of Cell with Acetate with one Without.

Date.	Time in minutes.	Current in ampères.	Crucible with no acetate.	Crucible with acetate.	Difference.
Feb. 13	123	·3084	2·5391	2·5467	+ ·0076
„ 14	120	·3521	2·8251	2·8368	+ ·0117
„ 16	125	·4047	3·3850	3·4016	+ ·0166
					The crucibles were made red-hot and re-weighed.
„ 18	...	...	3·3850	3·3966	+ ·0116
„ 18	120	·3416	3·0610	3·0777	+ ·0167
					Heated and re-weighed.
„ 19	...	...	3·0609	3·0685	+ ·0076
„ 19	120	·2794	2·2429	2·2512	+ ·0103
„ 22	120	·4510	3·2261	3·2473	+ ·0212
					Heated and re-weighed.
„ 23	...	...	3·2258	3·2431	+ ·0173
„ 23	...	...	2·9957	3·0114	+ ·1183

COMPARISON OF PURE NITRATE CELL WITH CHLORATE CELL.

Date.			Chlorate Cell.	Nitrate Cell.	Difference.
May 14	...	...	2·0904	2·0895	·0009
			(heated to redness and re-weighed).		
„ 15	...	...	2·0902	2·0891	·0011
June 5	120 min.		·3093	2·2270	2·2271	·0001
„ 7	130 „		·2852	2·4901	2·4900	·0001

The chlorate deposit after being heated to redness was dissolved in pure nitric acid and the solution tested for chloride, but none was found.

The silver cell being thus shown to be capable of working quite satisfactorily, the arrangement and comparison of copper cells were proceeded with. It was found in the previous experiments on copper that the deposits obtained on platinum wires gave much more concordant results than any other form of cell. This form of cell had been already used by Soret. It was accordingly decided to adopt that form. The cathodes were platinum wires

* Read before the Mathematical and Physical Science Section of the British Association at Birmingham, September 7th, 1886.

about 15 cm. long and 1 mm. in diameter, and the anodes were wires of electrolytic copper whose diameter was somewhat greater. It is, however, well known that the density of the solution alters very considerably in the neighbourhood of the cathode, and if the electrodes are vertical this effect is not so much interfered with by convection currents as when the electrodes are horizontal. The wires were therefore placed horizontally in the solution; for this purpose they were bent at right angles, and the one end fastened to a binding screw attached to a thick wooden rod that lay on the edges of a porcelain dish that contained the electrolyte. A number of cells were prepared respectively for 1, 2, 3 . . . . . up to 16 wires. The wires were arranged about two inches apart, and between them lay the anode wires attached to a similar piece of wood that rested on the other end of the dish; the wires in the same cell were put in multiple arc by a strip of copper laid along the wood, through which the binding screws passed. Some difficulty was met with in arranging that the anodes and cathodes did not touch, but with care it was surmounted. The solution was an approximately saturated solution of Hopkins and Willams's pure copper sulphate. No acid was added. The wires with their deposits were washed by rinsing them in several changes of distilled water and then dipped in alcohol and dried in an air-bath at a temperature of about 100° C.

In the experiments given below the copper deposits were brilliantly clean and generally showed no trace of oxidation on drying. The reason for this was never made clear; it is, however, easily recognised that under certain circumstances, defined perhaps by current density or the state of the solution, the copper deposits do not easily oxidise on drying, whereas in other experiments it seems almost impossible to dry them without considerable oxidation.

In all the experiments a rough tangent galvanometer was included in the circuit, so that any considerable variations of the current might be detected. A water or dilute copper sulphate cell, with copper electrodes whose distance apart could be adjusted, was also included to serve the purpose of a rheostat.

In a first series of experiments a silver cell was compared with each one of the copper wire cells in turn; the results are given in the following table:—

TABLE I.—*Comparison of Amounts of Silver and Copper Deposits.*

Date.	Time in min.	No. of wires.	Cu. deposit.	Ag. deposit.	Ratio.	Current in ampères.
June 10	145	1	·7309	2·4848	3·400	·2553
,, 11	120	2	·9268	3·1445	3·393	·3903
,, 11	120	3	·7651	2·5967	3·394	·3222
,, 12	115	4	1·0384	3·5130	3·383	·4549
July 7	120	2	·8417	2·8571	3·394	·3546
,, 7	120	1	·9245	3·1401	3·397	·3897
,, 8	120	3	·9764	3·3186	3·399	·3954
,, 8	—	4	·9740	3·3137	3·402	—
,, 8	120	5	·4206	1·4332	3·408	·1778
,, 9	120	6	·9969	3·3872	3·398	·4203
,, 9	—	7	·9482	3·2297	3·406	—
,, 10	120	8	·9471	3·2268	3·407	·4004
,, 10	120	9	1·1369	3·8721	3·406	·4806
,, 11	123	10	1·1261	3·8383	3·408	·4648
,, 11	123	11	1·0792	3·6783	3·408	·4454
,, 14	125	12	1·0416	3·5610	3·419	·4248
,, 14	128	1	·7318	2·4876	3·399	·2895
,, 17	125	2	·7577	2·5770	3·401	·3071
Mean					3·4010	

TABLE II.—*I. At the Cavendish Laboratory.*

Date.	Time in min.	Weight of silver in grms.	Ratio of weight of silver to weight of copper. For 1 wire.	For 2 wires.	For 4 wires	For 8 wires.	For 16 wires.	Current in amps.	Remarks
Oct. 10	150	·9717	3·407	3·414	3·417	3·416	3·419	·1113	Galvanometer deflection variable. In the 4-wire cell 3 wires only received deposit.
,, 20	300	2·7019	3·401	3·408	3·409	3·420	3·447	·1341	Galvanometer deflection variable. In the 4-wire cell 3 wires only received deposits.
,, 26	170	3·3682	3·398	3·398	3·397	3·401	3·407	·2951	Galvanometer deflection variable. "One wire" slightly discoloured.
,, 29	120	2·8930	3·397	3·398	3·409	—	3·414	·3591	—
II. At Emmanuel College.									
Nov. 27	120	3·9089	3·401	3·404	3·405	—	—	·3229	—
Dec. 10	110*	3·0239	3·413	—	—	3·411	3·408	·4081	Copper left in hot chamber too long, and was discoloured.
,, 15	120	4·9954	3·397	3·399	3·400	3·402	3·408	·6202	—
,, 16	150	4·4393	3·398	3·401	3·400	3·403	3·398	·4629	—
,, 17	120	4·0895	deposit loose	3·398	3·398	3·403	3·406	·5076	—
,, 18	120	5·1570	—	3·400	3·399	contact	3·400	·6399	A copper crucible in the same circuit gave 3·407

* Discarded.

It will be seen that the extreme error of the values from the mean amounts to rather less than ½ per cent.; the errors are irregular, but the difficulty of keeping the current constant was very great; in some cases there was considerable difference, so that no inferences as to the effect of current density could be drawn. The arrangement was therefore altered, and five copper cells containing respectively 1, 2, 4, 8, and 16 wires, were all included in the same circuit with one silver cell. The electromotive force was obtained from 12 storage cells, or from Grove's cells. The observations are included in the first part of Table II. There was still some difficulty in keeping the current constant, and the apparatus was in consequence transferred to Emmanuel College, where a dynamo working at 110 volts for electric lighting was available; a satisfactory series of observations was obtained, shown in the latter part of Table II.

DISCUSSION OF THE OBSERVATIONS.

The numbers quoted in the table give the ratios of the amounts of silver to the corresponding amounts of copper deposited to the 4th significant figure. The balance used was a triangular beam Oertling, which could be relied upon for an accuracy reaching 0·1 mgm. The copper deposits generally amounted to about 1 gramme, and the accuracy of the weighings (corrected when necessary for the differences in the buoyancy of the air at the times of the initial and final determination of the weights) may be assigned as ·01 per cent. for copper deposits, and ·003 per cent. for silver. The numbers in the table are carried to one place less than the weighings permit. This is done intentionally in order to enable the reader to obtain a better general idea of the whole series of observations. It is easily seen that the differences in the table are real differences, and correspond to some real characteristic of the electrolytic action in the cells. A glance at the sets of observations belonging to the same experiment is sufficient to suggest a diminution of the amount of copper deposited as the current density diminishes. The area of each wire was about 5 square centimetres, so that the current density varies for the observations in Table II. between ·001 and ·15 ampère per square centimetre, and practically includes all current densities that can come under observation with this form of cell. In some cases the density was so great in the "one-wire cell" that the copper deposit was flocculent, and could not be weighed in consequence; and in some of the sixteen wires the deposit was not sufficient to cover the wires, but occurred in patches with small groups of copper masses.

If we proceed, on the assumption of the accuracy of Faraday's law, to attempt to explain the observed differences, we must first look to the action of the solution upon the deposit, since it is known that such an action actually takes place when copper is immersed in a solution of sulphate, and that the weight of copper might be reduced by solution. This action is said to depend upon the solution and the temperature. These considerations make it difficult to infer the action in the cell from that upon a wire without a current flowing; for, in the first place, the solution is weakened in the immediate neighbourhood of the cathode by the electrolysis; and, in the second place, the temperature is altered by the current itself, and was sensibly different in the different cells in some of the experiments; but to measure the temperature and allow for it is not very practicable, as it is not uniform throughout the cell.

Further, there may possibly be a division of the current between the salt and the solvent, and any action of the kind would probably have an effect upon the action of the solution on the cathode.

The only plan that has suggested itself to me is to arrange the observations in the order of current density, and to see if any correction could be applied that would make the observations fairly comparable. This may fairly be applied, since the disturbing causes I have mentioned depend upon the current density.

In order to put this to the test, I have assumed in the first place that the action upon the deposit may be represented by an expression of the same form as would be required to represent the action of the solvent upon a wire immersed in the solution without any current. This we may take to be (for the comparatively short times of the experiments) a case of solution going in at a constant rate, and proportional to the area exposed. Thus, if δ be the actual loss of copper in an experiment when the area exposed is A, and the time t, we shall take

$$\delta = k \, \text{A} \, t,$$

and shall investigate whether a constant value of k can be taken to bring the observations into agreement. It is easily seen that this is equivalent to $\frac{\delta}{c} = \frac{k'}{d}$ where c is the total amount of copper deposited during the experiment, and δ the current-density; and where k' is also constant, but numerically different from k. In words we may express this by saying that the fractional correction is inversely proportional to the current-density.

LAW OF VARIATION OF THE DEPOSIT WITH CURRENT-DENSITY.

It is difficult to settle what value to assume for k'. If k' be a true constant, its value can of course be calculated from any pair of observed results; but the magnitude of possible experimental errors, in comparison with that of the quantity under consideration, makes it highly improbable that the results would be at all concordant. It will at any rate be well, in order to avoid a possible error in the weighing of the silver, to use observations belonging to the same experiment for determining the value of k'. I have determined the values of k' for several pairs of observations, taken somewhat at random, with the following results (Table III.):—

TABLE III.

Experiment.	Range of current-density.	k'.
Oct. 10	·0014 – ·023	·0000052
„ 20	·0017 – ·026	·000025
„ 26	·0037 – ·015	·000014
„ 29	·0045 – ·036	·000024
Dec. 15	·0077 – ·0310	·000025
„ 16	·0115 – ·092	·000017
„ 17	·0063 – ·051	·000017

The values of k' thus obtained are not very concordant. It must, however, be remembered that it is difficult to assign with confidence a numerical value to the current-density, since the effective area of the copper surface may be practically very different from that of the platinum on which the copper is deposited. In the expectation that the action of the solution upon the copper when no current is flowing might help to decide which value of k' to take, the "one wire" and "16 wires" of October 20th were replaced in the solution, after the weighing was completed, and remained there for the time of duration of the experiment, viz., five hours. The "one wire" lost ·0008 gm., and the "16 wires," ·0110 gm. This gives a loss of ·0007 gm. per wire, and corresponds to a value of $k' = ·000025$. On November 27th a loose copper wire was left in each of the cells during the experiment; and the mean loss of each of the wires during the time was ·0003 gm., which corresponds to approximately the same value. It will, therefore, be well to see what effect the correction of the weighings on the hypothesis that $k' = ·000025$ would have upon the tabulated results. The correction may be introduced by adding ·00014 gm. to the weight of each wire immersed for each hour during which the experiment lasts. The following table shows the weights of copper as thus corrected (Table IV.) :—

TABLE IV.

Date.	1 wire.	2 wires.	4 wires.	8 wires.	16 wires.	Mean.	Mean per centage.
Oct. 10	·2855	·2853	·2853	·2869	·2889	·2864	0·4
„ 20	·7952	·7942	·7941	·7957	·7949	·7948	0·06
„ 26	·9932	·9922	·9931	·9934	·9950	·9934	0·06
„ 29	·8519	·8516	·8520	—	·8518	·8518	0·02
Nov. 27	1·1498	1·1490	1·1489	—	—	1·1492	0·04
Dec. 15	1·4708	1·4700	1·4703	1·4704	1·4698	1·4703	0·02
„ 16	1·1888	1·1882	1·1892	1·1894	1·1932	1·1898	0·11
„ 17	—	1·2039	1·2043	1·2037	1·2048	1·2042	0·03
„ 18	—	1·5172	1·5183	—	1·5215	1·5190	0·11

An examination of this table shows that, with some few exceptions, the results, as corrected, are very fairly concordant. That no value of k' could be found which would apply equally to all the observations is obvious from the discordance in the values of k' tabulated above. A striking feature of the table is that the numbers under the heading of "2 wires" seem now to be the minimum values of the table; the "1 wire" values are all greater; and the numbers in the other columns are very rarely less, and then only by very small quantities. This shows that the correction applied is probably too large, though it is sometimes very successful. It is probable that the correction ought not to be applied when the current density is very great, as the difference between the "1 wire" and "2 wires" is increased by the correction, though not entirely due to it. This, as already pointed out, is probably *à priori*, since the more rapid deposition of copper would weaken the solution in the immediate neighbourhood of the cathode. The correction may, however, be fairly adopted for the smaller current densities. It appears on examination of the current densities that the exceptional cases do not arise when the current density is below ·02 ampère per square centimetre, so that the weights of copper deposited with currents of current density less than ·02 ampère per square centimetre, may be corrected by multiplication by a factor $1 + \frac{k'}{d}$, where d is the current density, and k' a constant not differing much from ·00002.*

CHEMICAL EQUIVALENT OF COPPER.

We have now to compare the results obtained for the ratio of the chemical equivalent of silver to that of copper with those obtained by purely chemical methods, in order to ascertain whether or not Faraday's law is strictly applicable in the case of silver and copper. If we take the results given in Landolt and Börnstein's "Physikalisch-Chemische Tabellen," we find the atomic weight of silver given as 107·66 by Meyer, and 107·675 by Clark, and the accuracy is stated as being within ·05; that of copper is quoted as 63·18 from Meyer, and 63·17 from Clarke, with a possible error of ± ·5. This would give a value for the ratio of the chemical equivalents of silver and copper equal to 3·4086; or, allowing the fullest margin for error, the value lies between 3·38 and 3·44; so that the values obtained by the deposition of silver and copper seem to be all within the limits of error thus assigned; and we cannot, therefore, test the accuracy of Faraday's law until the value of the chemical equivalent of copper can be assigned with greater accuracy than appears at present to be practicable. We may, however, notice that the value 3·4086 is that which would be obtained with comparatively very small current densities, and occupies a place in the middle of a continuous series, and there seems to be no reason in the electrolytic behaviour of the cells for accepting that value as indicating a limiting result. We may therefore fairly approach the question the other way, and, using the observations to calculate the chemical equivalent of copper by Faraday's law, consider the results which follow. If we assume, as we seem fairly entitled to do, that the differences of the weights for different current densities are due to the solution of the deposited copper, it follows (assuming Faraday's law), that we must get a nearer approximation to the true amount of copper equivalent to the amount of silver deposited the greater the current density. The value would be affected by the correction discussed above; but it has been already stated that it is unsafe to apply the correction, or, at any rate, to assign to the value that of k' assigned above. But the consideration of that correction serves us to this extent, viz., to show that for current densities above ·02 its value must be very small indeed, reaching, as a matter of fact, with the value of $k = ·00002$, to less than one milligramme per gramme. But in determining by Faraday's law as accurately as possible the chemical equivalent of copper from that of silver, the correction cannot be disregarded without sufficient reasons. Some reasons for that course have been given, but in order to test further whether or not the correction should be applied I have plotted the observations on sectional paper, taking as ordinates the ratios of copper to silver, and as abscissæ the reciprocals of current-densities. If the correction should be applied throughout, the grouping of the observations should show a straight line inclined to the axis of current-densities. I have adopted this method of combining the observations belonging to different experiments for this purpose, in preference to the arithmetical one of taking means, because the latter is liable to be seriously affected by a set of observations, each one of which is far from the mean in the same direction, but which does not extend throughout the whole range. In the estimation by eye of a mean result of plotted observations allowance can be made for the effect such observations produce, whereas they may give a false appearance of general law to a set of arithmetical means.

The observations included in the Table II. when plotted do not give any indication of the divergence of the mean ordinates from a straight line parallel to the axis of reciprocals of current densities until the current density is less than ·02, and the straight line passing through the "centre of gravity" of the group of observations for highest current densities, and inclined to the axis with the angle given by the value $k' = ·000025$, would leave all the rest of the observations except three on one side of it; but a very fair result is obtained if the value of k' be somewhat reduced, and the line be drawn at the corresponding less inclination through the point corresponding to the "centre of gravity" of observations about the current density ·02. If we must take a straight line inclined to the axis as representing the results, the one which must be selected has an inclination to the axis of about one-half that given by $k' = ·000025$, and even that leaves on one side of it nearly the whole group of observations whose current densities have reciprocals between 50 and 30. Further, the values of the ratios obtained from the observations for current densities above ·02 are remarkably close, except in two instances; in one the ratio is very high, with a high current density, and differs widely from other observations at about the same current density; the other is very low, and belongs to an experiment which gives a series of very low values; this has been rejected because the wire which gave it was marked in the note-book as discoloured, *i.e.*, oxidised, at the time of weighing.

TABLE V.

Current densities.	Ratios observed.	Ratios with the correction ($k' = ·000012$).
·124	3·3968	3·3965
·104	3·4005	3·4001
·093	3·3984	3·3979
·072	3·3971	3·3965
·064	3·4004	3·3997
·062	3·3994	3·3987
·052	3·4035	3·4027
·051	3·3982	3·3974
·046	3·4009	3·4000
·036	3·3984	3·3972
·032	3·3990	3·3977
·031	3·3998	3·3984
·027	3·4014	3·3998
·026	3·4056	3·4040
·025	3·3982	3·3966
Mean	3·39983	3·39888
Mean error ...	·00175	·00151

* The values obtained by Lord Rayleigh with copper bowls (*Phil. Tr.*, Part II., 1884, p. 458) are :—
Current density, about ·012; ratio of equivalent, 3·405
„ „ „ ·026; „ „ 3·408
„ „ 3·404

In order, therefore, to obtain the value of the chemical equivalent by this method, I have taken all the values obtained for current densities greater than ·025 ampère per square centimetre. They are included in table V.

I have included in the same table the values obtained when the correction for the current density ($k' = ·000012$) is introduced, in order that an opinion may be formed as to the magnitude of the difference produced. It will be seen that the amount of difference corresponds to an error in weighing of only 0·3 milligramme per gramme. I have given reasons for preferring the value as calculated without the introduction of this correction, and from the circumstance already pointed out, viz., that after the correction $k' = ·000025$ is introduced, the "2 wire" values are minima, it would seem likely that the deposit obtained with the highest current density may be too great in consequence of the operation of some action which is not accounted for. To decide this point requires measurements to a degree of accuracy beyond that reached in the present observations, so that we may set down the ratio of the chemical equivalent of silver to that of copper, as obtained by this method, as being

3·39983,

with a mean error of ± ·00175 in the observations.

THE ATOMIC WEIGHT OF COPPER.

It will be at once noticed that the value obtained for the ratio of the equivalent differs by only 17 parts in 300,000 from the number 3·4000, and there is some indication that the observed value is too small; we may therefore accept the observations as showing the ratio to approach very nearly indeed to 3·4000. This gives for the ratio of the atomic weight of silver to that of copper the ratio of the whole numbers 17 : 10. If we take the atomic weight of silver as 107·66, the atomic weight of copper will be 63·333. This result gives some striking relations; it gives, in fact, for the atomic weight of silver the number $\frac{19 \times 17}{3}$, and for that of copper $\frac{19 \times 10}{3}$, and therefore gives both as one-third of whole numbers. The atomic weight of silver is one of the most accurately determined of all, and the number here assigned to copper is within the limits of error allowed by L. Meyer; so that these remarkable relations may perhaps offer some reason for considering the value of the atomic weight of copper as deduced from Faraday's law as being worthy of consideration.

A number of speculations are suggested by the relations between the numbers thus arrived at; but it is not necessary to discuss them here.

ELECTRICITY AND THE BIRTHDAY OF THE GERMAN EMPEROR.

THE grand illuminations which the city of Berlin got up in honour of the 90th birthday of the emperor, as celebrated there on the 22nd March, was distinguished not merely by the wealth of light, but also by the manifold and extended applications of the electric light.

The French and the German Cathedrals in the Gensdarm Market had on both their towers 24 arc lamps, each of 25 ampères. The current for these lamps was furnished by the Central Station of the Joint Stock Municipal Electric Works at No. 44 in the Markgrafen-strasse. All the 24 lamps were arranged singly on parallel conductors and required together about 100 horse-power. The Central Station of the German Edison Company, 85, Friedrich-strasse, had on its front about 1,000 glow lamps, each giving about 10 candles. All the windows from the first-floor up to the roof were bordered with glow lamps of the most varied colours. The middle window was surrounded by a particularly beautiful arrangement of small glow lamps of a dead white in the midst of which shone a colossal bust of the emperor.

The Central Station of the joint stock company "passage" in "Unter den Linden" had on the principal front of the building 20 arc lamps arranged with garlands, presenting a splendid spectacle.

The Central Station, No. 17, Benth-strasse, had on a scaffold an enormous W formed of 15 arc lamps and surmounted by a crown in glow lamps.

Every house which has either an especial installation or is connected with one of the central stations, had its front adorned with glow lamps in the most multiform variations; the initials of the names of the Emperor and Empress, the dates, &c., were seen shining in the most varied colours, combined with arc lamps in coloured lanterns.

On some buildings a wonderful effect was produced by green garlands intertwined among green glow lamps. The Academy of Arts and the Royal Library were illuminated with arc lamps.

How extensive must have been the application of the electric light on this occasion will appear from the fact that the German Edison Company alone furnished here and elsewhere the fittings for about 5,000 glow-lamps. At 10 p.m., on the extinction of many of the decorations, the strength of the current fell within ten minutes by about 2,000 lamps.

The gigantic advantages which the electric light has effected, slowly but safely, in the capital of the German Empire, was brought clearly before the world by these surprising facts. If the gasworks still maintained that the application of the electric light in Berlin was too trifling to make itself felt as a competitor, this view will no longer be found in harmony with actual facts.

The two large central stations of the Edison Company and its filial, the Municipal Electrical Works, are now being extended so that each can supply 20,000 lamps burning at once, and two new central stations are about to be erected.

The time is probably not far distant when the number of glow lamps in Berlin will be greater than that in New York.

J. ZACHARIAS.

REVIEWS.

Joint Scientific Papers of J. P. Joule. Published by the Physical Society of London. London: Taylor and Francis, Red Lion Court, Fleet Street.

The subjects dealt with in these papers are but three in number, the first being "Experiments and Observations on the Mechanical Powers of Electro-Magnetism, Steam and Horses," by Rev. W. Scoresby and J. P. Joule; the second "On Atomic Volume," by Dr. Lyon Playfair and J. P. Joule; and the third "On the Thermal Effects experienced by Air rushing through small Apertures," by J. P. Joule and W. Thomson. The result that the authors arrive at in the first paper is, that the maximum available duty of an electro-magnetic engine worked from a Daniell's battery is 80 lbs. raised one foot high for each grain of zinc consumed, or about half the theoretical maximum of duty. It is interesting to note that the authors calculate that one quarter of the whole amount of *vis viva* generated by the combustion of food in the animal frame in the case of a horse is capable of producing a useful mechanical effect, and that therefore the animal frame, though destined to fulfil so many other ends is, as an engine, more perfect in the economy of *vis viva* than the best of human contrivances.

Electricity in the Treatment of Disease: A Practical Guide to its Application; what it is, and what it will Accomplish. By James R. Tumner, M.R.C.S., Eng. London: E. W. Allen, 12, Ave Maria Lane, Paternoster Row.

The amount of unscientific rubbish which has been written on the subject of the application of electricity to medical purposes makes it quite refreshing to meet a work like the small book of Mr. Tumner. The author quite sees the unsatisfactory condition in which the subject is, in many respects, at present, more especially as regards the quantitative view of the question; thus we have the strengths of the currents applied for certain purposes generally characterised as "mild," "medium," or "strong," explanations which are but little more definite than that of the countryman who defined the size of a certain article as being equal to that of a lump of chalk. The author says "it is to be hoped

that the time will come when we shall be able to prescribe so many farads of electricity as we now do so many drops or grains of a drug. With reference to electric baths the author gives some very sensible remarks, and reasonably comes to the conclusion that all the benefit that can be obtained from these baths can be better obtained by the use of rheophores.

Journal of the Society of Telegraph Engineers. No. 64.

This number contains, amongst other things, the paper by Mr. Kapp, "On the Predetermination of the Characteristics of Dynamos;" "Some Experiments on Secondary Cells," by J. Swinburne; "Some Magnetic Problems," by Prof. Forbes. Some "original communications" and the usual extracts complete the volume.

A METHOD OF CHARGING SECONDARY BATTERIES BY MEANS OF A MAGNETO-ELECTRICAL MACHINE, THE POTENTIAL OF WHICH IS MUCH LOWER THAN THAT OF THE CELLS JOINED UP IN SERIES.

IT is sometimes inconvenient to set up a dynamo and engine of considerable size for charging secondary batteries. As the following method by which only a small machine and motor is used has answered well for several years, it may perhaps be of use to others who, like myself, are engaged in physical work. A small water motor drives a small magneto Gramme machine, the same motor by means of wheel work, for reducing velocity, switches the machine on to one cell of the battery at a time; such being the case, the E.M.F. of the charging machine need only be a little *in excess* of that of each cell, the method of charging in parallel was tried, but it did not answer well, as a slight difference of internal resistance of the cells caused the current to be unevenly distributed amongst them. A somewhat similar method of switching in cells by clock work has of late been introduced into the chlorine battery of Mr. Upward. The idea of putting the current on to one cell at a time seems to be due to Poggendorff (if I remember right), *Electrical Magazine* for 1842. It may be mentioned for the benefit of those who use chlorine gas, that it can be readily produced in abundance by the electrolytes of hydrochloric acid (carbon electrodes being used, as platinum is acted on by the gas as it comes off). A small motor and electric machine effects this constantly in the laboratory.

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HOCHHAUSEN'S ELECTRIC MOTOR.

THE demand for motors on arc light circuits or for constant current has led Mr. Wm. Hochhausen, the electrician of the Excelsior Electric Company, to design a machine, which, with fixed brushes, should regulate so as to keep constant speed with a variable load, and without the interposition of external resistance. The motor has a single magnetic circuit in which the armature is included. The latter is mounted on bearings at the top of two arms which rise from the base, which also constitute the bearing of the electro-magnets, which have wrought-iron cores and cast-iron pole pieces.

The regulation of the motor is effected by varying the intensity of the magnetic field to correspond with the load. For this purpose the two field coils are divided into ten sections, the ends of which are brought to consecutive contact strips below the armature.

The governor is of the centrifugal type and is held in an extension bearing at one end of the armature shaft. The governor acts upon an arm which extends downwardly and operates upon a contact maker which touches the various contact strips to which the field coils are connected. Thus, when the motor, which is series wound, runs with full load and at normal speed, all the sections of the field coils are in action; as the load diminishes the governor expands from the momentarily increased speed and cuts out successive coils in the field. This reduces the magnetic strength of the latter, and brings the motor back to the same speed as before. Conversely, when the load is increased, the speed is reduced for an instant, the governor contracts and puts additional field coils in circuit to correspond with the increased load.

The machine is designed for 3 H.P. and runs at 2,000 revolutions per minute, taking a 10 ampère current, such as is largely employed in arc lighting. Its weight is 250 pounds.

Mr. Hochhausen apparently does not know that a plain shunt motor will regulate itself with varying loads quite as well as his complicated governor arrangement for cutting out field coils. Moreover, in the case of a shunt motor with its constant field, he can get a higher average efficiency than is possible when the strength of the field is varied. According to the *Electrical World*, Mr. Hochhausen calculates the efficiency of his motor by the loss of energy through the resistance and ignores all other losses; "the resistance," says our contemporary, "of the armature is 1 ohm, and that of the full field also 1 ohm—*hence* the energy lost in the motor *at full speed*, with 10 ampères, is 200 watts, and as the motor delivers 3 H.P., or 2,238 watts, its efficiency is thus 90 *per cent.*"

We do not know what he means by *full speed*, for in another paragraph it is stated that "the action of the governor is quite sensitive, as we had occasion to witness recently, and Mr. Hochhausen asserts that the regulation is within 2 per cent. between full load and no load."

Considering that this 3 H.P. motor weighs 250 lbs. we think that its normal speed of 2,000 revolutions per minute is excessive, and we can point to motors in this country, which at such a speed and power, weigh 50 per cent. less, and whose internal resistance is not more than one-half that adopted by Mr. Hochhausen in this particular machine; and which, if we calculated the efficiency according to the above method, would come out about 96 per cent., and by increasing the size of such a machine, we might get any "efficiency" we chose. Our contemporary further remarks:—"When the motor runs without load all the field coils are cut out, so that the resistance is that of the armature alone, in that case the energy absorbed by the motor is 100 watts"! Does this mean the current squared? What becomes of the E.M.F. at the terminals, which was 223·8 volts when the motor gave 3 H.P.?

Electric Motors for Power Purposes.—The various recent discussions of the electric motor question have already been remarkably beneficial, says the New York *Electrical World*. They have arrested attention on the fact that the motor is to-day a practical, efficient, and economical machine, and they have led many people to consider their use who but a month or two ago had not the least idea that there was any such useful apparatus in existence. We speak on this point with full knowledge, having been ourselves applied to by a number of power users—principally printers—for information as to the manner in which they could avail themselves of the electric motor. On inquiry we find that most of them had not, until the present year, entertained any idea that their special necessities could be met by electricity, but having now satisfied themselves from what they had heard and seen, they were anxious to get the services of a power so cheap, handy and docile. We have ourselves spoken with a great many users of electric motors, and have yet to meet the man who did not prefer them to anything else he had tried.

NOTES.

The Electric Light at Taunton.—Mr. H. G. Massingham, who was mainly instrumental in the introduction of the electric light in Taunton and in the formation of the local company, a week or so ago invited a party of friends from Bristol and Bath to witness the successful operation of the system of street lighting by electricity. Only the principal thoroughfares are supplied, the arc lamps being elevated on columns 25 feet in height with an average of 60 feet between them. The verdict of the visitors was that the streets were well lighted and by contrast with the old gas lamps, faintly glimmering in the bye-streets, were made to look like "the light of other days," as the *Bath Chronicle* puts it. Several of the principal shopkeepers who have adopted the electric light, opened their establishments to the visitors and demonstrated how completely the lighting arrangements were under control. In the streets there are 30 lamps in use, the charge per lamp per annum being £21 10s., which charge includes attendance and repairs. St. James's Church is lighted by five arc lamps, the cost of which is £25 per annum for their use at the Sunday evening services. Our informant states that on the return journey it was evident that the Taunton experiment had created a very favourable, not to say enthusiastic, impression on the minds of the visitors. How the electric light could be introduced at home was seriously discussed, and so completely had the difficulties vanished to the more sanguine that one ventured to prophecy that within a twelvemonth Bath would share the honour with Taunton of relying on arc and incandescent lamps for the illumination of some at least of its commercial establishments.

Electric Lighting Act Amendment.—The Bill of Lord Thurlow for the amendment of the Electric Lighting Act of 1882 was read a third time in the House of Lords on the 31st ult. and passed.

Electric Lighting at Glossop.—In our last issue we published a paragraph from the Manchester *City News* which seems originally to have appeared in the *Gas World*. Last week letters appeared in the Manchester paper questioning the accuracy of the paragraph. Messrs. Sanderson, Ruddle & Co., Manchester, stated that in the mill at Hadfield, to which reference was made, there were 2,000 burners, which, assuming they passed 5 cubic feet per hour and burned 300 hours, would give a yearly consumption of 3,000,000 cubic feet, which, at 3s. 6d. per thousand cubic feet, would give a total bill of £525 against the £191 first stated. They further said: "There is not the least doubt that the electric light can compete favourably with gas even at Manchester prices, as the results obtained at a local mill, having some 900 incandescent lamps in use for four years, show that an annual saving of over £140 is effected as compared with the former cost of lighting with gas." Mr. J. R. Williamson, manager of the Manchester District Edison's Electric Light Company, also wrote to the effect that nearly £400 instead of £191 was previously paid for the gas which has been substituted by the electric light. He adds that the sum mentioned as having been paid for electric plant (£3,500) is grossly exaggerated. Since the publication of these letters the *Gas World* states that it has taken steps to verify its statements, and finds that they were quite correct. Mr. Dalgleish, the engineer of the gasworks at Glossop, wrote that in the mill in question the meter power was for 840 lights, capable of supplying 1,680 jets; that the gas consumed for the year ending 31st December, 1885, was 1,141,900 cubic feet; that this was charged at 3s. 1d. per thousand net, or £176 3s. 2d.; and that with meter rent added the total sum reached £191 7s. 6d. He adds that the foreman who superintended the work connected with the electric light installation told him the estimated cost was £3,000, but that it would actually cost £3,500. Summing up his letter Mr. Dalgleish said: "This shows that the electricians are wrong on every point. The consumption of gas is over-stated by nearly 2,000,000 cubic feet; the price of gas is over-stated by 5d. per thousand cubic feet—net; the nominal meter-power 840 lights equals, say 1,680 against 2,000; the amount estimated for gas by one, £334, is over-stated; the amount said to be paid, as stated by Edison's manager, is £209 over-stated; and gas is, and will have to be used besides electric light. Let electric light compete successfully, financially, in Paris, where gas is more than double Manchester prices, before it talks of Manchester or adjoining towns."

The Thomson-Houston Company.—Business has been very active with the Thomson-Houston Company since the first of the year, and the following is a partial list of plants installed since January 1st:—Terre Haute, Ind., 45 arc; Kansas City, Mo., 90 arc; Reno, Nev., 45 arc; Larned, Krn., 18 arc; Cleveland, O., 800 incandescent; Milwaukee, Wis., 100 arc; Lima, O., 45 arc; Lima, O., 400 incandescent; Joplin, Mo., 60 arc; Hillsdale, Mich., 45 arc; Sheboygan, Mich., 45 arc; Miles City, Mont., 30 arc; Bozeman, Mont., 30 arc; Billings, Mont., 30 arc; Jackson, Mich., 100 arc; Battle Creek, Mich., 100 arc; Wahoo, Neb., 300 incandescent; Litchfield, Ill., 30 arc; Atchison, Kan., 30 arc; Houghton, Kan., 45 arc; Duluth, Minn., 25 arc; St. Louis, Mo., 50 arc; Warsaw, Ind., 30 arc; San Francisco, Cal., 50 arc; Woodlawn, Cal., 45 arc; Seattle, Wash. Ter., 25 arc; Nevada, Mo., 30 arc; Ryerson Building, Chicago, 20 arc; Studebaker Bros., Chicago, 45 arc; Studebaker Bros., Chicago, 75 incandescent. The company has now on hand unfulfilled contracts in the West for 475 arc lights and 3,600 incandescents.

Electric Lighting at Hastings.—On Saturday, the 2nd inst., a party of gentlemen from Croydon (by the special request of the Anglo-American Brush Corporation) visited the works of the Hastings and St. Leonards-on-Sea Electric Light Company, Limited, to inspect the system of lighting the borough and also that of incandescent lighting. Having thoroughly witnessed the working and seen the perfect steadiness of the incandescent lamps in several business establishments, the party returned evidently well pleased and gratified with such a successful installation. The company's wires are all underground, and light is supplied at a distance of a mile and a half from the central lighting station. Some members of the Croydon Corporation were in the party, also advising electricians.

Lighting of Trains in Glasgow.—The cables and rails for conveying the current to the carriages passing through the underground system of the North British Railway have been completed some little time, over the whole distance from College Street to Finnieston Street, and fair progress is being made with fitting the carriages with lamps, &c. It is, however, a matter for regret that the very satisfactory results shown in the first lot of carriages fitted up is now being departed from. Instead of having one well-fed 16-C.P. lamp, there is now being substituted two poorly-fed 5-C.P., which give a most aggravating apology for light, as it is impossible to read by it; in fact, the result is a stigma upon electric lighting, and if such be persisted in will detract greatly from the good name which the earlier lighting was winning for the North British management.

Telephone Service (?) in London.—The latest device of the United Telephone Company, says *Money*, is to ring up subscribers with praiseworthy punctuality every morning, and ask them "if they are all right," and as soon as they receive an answer in the affirmative, communication is immediately cut off and interrupted for the rest of the day. This farcical formality may be very amusing to the exchange clerks, but it is decidedly annoying and aggravating to subscribers who are subjected to it.

Sea Telephony.—A report from Fort Myers, Florida, where Mr. Edison is sojourning, says that he is working on his sea telephone. The inventor says that already he can transmit sound between two vessels from three to four miles distant, the one from the other, and he seems confident, now the principle is established, that he will be able to increase the distance between his stations as the apparatus becomes more perfect. Up to the present he has not succeeded in transmitting articulate speech, nor is this essential to the success of the system. By means of submarine explosions, he is enabled to form a series of short and long sounds in sequence, and by these, as in the Morse system of telegraphy, words and sentences can readily be transmitted.

Storms and the Spanish Telegraphs.—A Madrid telegram announces that telegraphic communication with foreign countries is greatly delayed by storms.

Electricity at Newcastle Exhibition. — One of the features of the coming Jubilee Exhibition at Newcastle will be the electric lighting of the building. The Executive have decided to utilise electricity to its fullest extent, and accordingly some remarkable novelties in electrical engineering are already in process of construction. By special arrangements the art gallery lamps will be so arranged as to throw the most of the light directly on the pictures. In the theatre the lights will be made variable by means of resistance coils of iron wire which have been arranged outside; and by means of a switch board placed at a corner of the stage, and under the full control of the stage manager, the whole of the lights in the auditorium will be enabled to be reduced from 16 candle-power to about 1 candle-power. Besides an electrical railway, there will be an electrical smithy, where experiments will be made in the welding of metals by the assistance of a strong current. A marvellous machine for rivetting will also be shown.

Chatterton's Compound.—Mr. Willoughby Smith writes as follows:—"The compound known as 'Chatterton's compound,' referred to by Charles Bright, Jun., in his letter published in your journal of the 1st inst., was patented by me in 1858, for 'insulating electric telegraph wires.' The number of the patent is 1,811. Mr. Chatterton in the same year patented a method *of applying* 'Willoughby Smith's or other compounds' for the same purpose. The two other claims in Mr. Chatterton's patent were never, for obvious reasons, adopted. They are:—'I also electroplate the copper wires which I employ for electric conductors in order to render them more suitable to be used for this purpose.' 'In long lengths of telegraph lines, I gradually diminish the size of the conducting wires so that as the electric currents become weaker they will have suitably sized conductors.'"

The Lithanode Battery. — We have had many enquiries respecting the uses to which the Union Company is putting the lithanode battery of Mr. FitzGerald. Perhaps Mr. Jones, who has joined the directorate, is in a position to give this desirable information.

The Colonial Conference.—The opening sitting of the Colonial Conference was held at the Foreign Office on Monday, and Sir Henry Holland, Secretary of State for the Colonies, in his address, made the following references to cable matters:—With respect to telegraphic communication, I would point out in the first place the extraordinary growth of submarine telegraphy, to which Mr. Pender called my attention in a letter of the 28th of January. He there says: "Submarine telegraphy is of quite modern growth. Twenty years ago there were about 2,000 miles of cable laid, chiefly in the channel, and some of the earlier submarine cables that were laid were unfortunately so badly constructed that they were useless for work. I might quote, as an instance, the old Red Sea cable. Science has now, however, aided so greatly in the manufacture of cables, that they can at the present time be laid with comparatively little risk of breakage and with an almost certainty of efficient repair. These facts account for the rapid growth of the submarine telegraph system, which now embraces 107,000 miles, at a cost of something like thirty-seven millions sterling. I may mention, as a contrast, and to give an idea of the importance of this system, that the whole length of the land lines now in existence in the world is some 1,750,000 miles, which represent an estimated cost of £52,000,000. The submarine cable system is, with the exception of 7,000 miles, entirely under British control, and has been the result of private enterprise." I must add that I concur entirely in his observations that "The value of the submarine system as it is now controlled, under British management, it is impossible to over-rate, either from a political or commercial point of view. In regard to our enormous commerce and its relation to the movements of our great mercantile marine, both the one and the other are more or less controlled and influenced by our marine system. The economy in the working of ships is very great, indeed; and in commercial transactions there are few of any magnitude which do not involve the forwarding and receiving of telegraphic messages. These circumstances show that it is of great importance that the control of the telegraphs should be, as far as possible, in British hands; while it is of equal importance that the tariffs should be as low as it is possible to make them." I will now direct attention to a proposal to connect Canada and Australia by cable, upon which subject, papers will be circulated to you. The question of connecting Australia with Canada by cable, and so affording an alternative means of communication beyond those supplied by the Eastern Extension Telegraph, has been from time to time mentioned in connection with the Canadian Pacific Railway, but it was first brought formally to the notice of Her Majesty's Government on July 29th, 1886, by a letter from the High Commissioner for Canada. This letter, together with a report by the Superintendent of Electric Telegraphs, New South Wales, dated March 31st, 1886, will be found among the papers I am about to lay before you. The scheme is opposed by the companies which own the existing telegraph lines communicating with Australia, and on January 28th of this year I received from Mr. Pender a letter enclosing copies of letters and memoranda, which will also be found among the papers, suggesting that a reduction of the existing tariff charges might be effected upon a guarantee from the colonies. The promoters' scheme alluded to by Mr. Pender has not been communicated to Her Majesty's Government, and his own figures appear to be but a very rough estimate. They furnish, however, the only information I possess upon the matter. A very strong case would have to be made out to justify Her Majesty's Government in proposing to Parliament to provide a subsidy for maintaining a cable in competition with a telegraphic system which at any rate supplies the actual needs of the Imperial Government. I fear that at the present stage I can only invite the Australasian and Canadian members of the Conference to favour Her Majesty's Government with their views generally upon the scheme for laying a cable across the Pacific from Vancouver to some point in one of the Australasian colonies. The Australasian representatives will perhaps further consider, and favour Her Majesty's Government with their views upon, the general proposal to have a reduction of existing tariff charges under a guarantee from the colonies.

Tuesday's sitting of the conference was occupied with the discussion of the question of the naval defence of Australasia, and proceedings were "necessarily of a confidential nature." The subject of telegraphic and postal communication was down for discussion on Wednesday.

The Van Depoele Electric Roads.—The Van Depoele electric roads have lately been receiving visits from street railway officials of Cincinnati, Boston and other cities. The reports of the visiting committees have been favourable in every instance, the *Electrical World* states. A member of the Boston committee who visited Scranton afterwards, said :—"We went there without giving any notice of our purpose, and went over the line of the road in the cars and back, stopping at an intermediate point, and making, as far as we could, a careful examination of the road in its operation. We all came away satisfied that electricity as a motive power for street railways has come, and while many details of application and convenience will yet be added to it, the success of the thing seems to be assured. The car was geared for running five miles an hour up the heavy grades, and on the level stretches 15 miles an hour. Both rates of speed were easily made, and the car ran easily, steadily, and was in full control of the driver, if he may so be called. The motor is placed on the front platform, which is enclosed very much like a pilot house, where also is a hand-brake, by which the speed of the car is controlled and checked. The whole handling of the car is very simple and effective." He further said it was very probable that by next autumn his people would have several miles of electric railway in operation in and around Boston. A committee which visited Appleton, Wis., represented 96 miles of street railroad at Cincinnati, O., now using 250 cars and 1,900 horses. These visitors were also highly pleased; and well they might be, says our contemporary, for they saw an electric railroad which operates perfectly. The car on which they rode was loaded down to its utmost capacity with people, but it moved off easily and smoothly, just as it does every day in the year to the extent of 90 miles every 15 hours, down the avenue, around the curve on to Meade Street, around the curve on Pacific Street, down Pacific Street to Bellaire Park Bridge, down the hill on to the bridge, up the hill on an 8 per cent. grade with a curve, to a sharp curve around and on to the turn-table. The car was turned around and made the return trip, during which it easily ascended two grades, one of 4 per cent. and another of 5 per cent. There are five electric cars on the Appleton system, and three more have been ordered.

New Dynamo.—Messrs. Ganz & Co., of Buda-Pesth, *Industries* states, have just completed a new continuous current dynamo of the multipolar type, resembling in outward appearance their well-known alternate current machine. The dynamo is designed for an output of 35 ampères, and a pressure of 1,500 volts, or about 52,000 watts. The speed is 1,000 revolutions per minute.

The Price of Gas.—The South Metropolitan Gas Company recently notified that from April 1st, the price of gas would be reduced to all consumers, public and private, to 2s. 5d. per thousand cubic feet. The Gas Light and Coke Company has reduced its charge to the vestries in its district to 2s. 5d. per thousand, but private consumers will still have to pay 3s. The latter naturally think they have a grievance, and the vestries are publicly exhorted by one of them not to abandon their attempts to procure a general reduction.

The Chandler Engine.—Mr. F. D. Bumsted, of Hednesford, the maker of the Chandler high speed engine, which is a remarkably good one for electric lighting purposes, has found it advisable to have it on view in London, and has made arrangements by which it can be seen at any time at the establishment of Mr. James Keith, Holborn Viaduct.

Julien Cars in America.—A car fitted with Julien storage batteries and a Sprague motor is expected to be in operation in Boston in about a month. Mr. F. Kohl, of the Julien Company, has gone to St. Louis to put a storage street car in operation there, as the preliminary step to the adoption of electricity on one of the large roads.

Secondary Battery Litigation.—A dispatch of March 17th from Cleveland says: The Electrical Accumulator Company, of New York, entered in the United States Circuit Court here to-day two suits, which are practically one in aim, against the Brush Electric Company for alleged infringement of patent.

Another Big Brush Machine.—One of the new colossal Brush machines now building for the Cowles Electric Smelting and Aluminum Company, at the Brush Electric Company's works in Cleveland, is nearing completion. It will shortly be tested with a load equivalent to 5,000 incandescent lamps.

Demagnetising Watches.—A correspondent sends us the following account of a very simple method of demagnetising watches :—"My watch was very strongly magnetised, so that I could not depend on it at all for the correct time, as sometimes it gained and sometimes lost considerably. The watch was placed in a coil of wire completely surrounding it, this coil was circuited in series with a small alternating machine and an adjustable resistance, and when the current was first switched on all the resistance was taken out; it was then gradually all put in, and immediately the current was switched off, when no trace of magnetism was found about the watch. I may add that although this was about six weeks ago, the watch has since then kept excellent time."

Brooks's Underground System.—The Metropolitan Telephone and Telegraph Company, of New York city, is laying six 3-inch diameter iron pipes, each containing 400 conductors, No. 18 Birmingham gauge. Three pipes are laid side by side in the bottom of a wooden box, and three others are laid side by side over the lower three, and the intervening space is filled with pitch. They start from the new building on the north side of Liberty Street, and go eastward, crossing Broadway, thence on the east side of Broadway to Wall Street, east on Wall Street to New Street, thence the pipes diverge, supplying that portion of New York City south of Wall Street, and east of Broadway. All of the conductors are brought into the buildings directly under the sidewalk. The number of conductors thus brought in vary from two to seventy-five; where the larger number are brought in it is the intention to distribute them from the back of the building to other buildings in that block. This is the Brooks oil system, and the company has arranged for its use throughout the city, so far as permitted to do so by the city authorities.

Football Match.—A match between the Electrical Engineers F.C. (Hanover Square School of Telegraphy) and the Resistance F.C. (Messrs. Woodhouse & Rawson's staff) was played at Balham on Saturday, April 2nd, and resulted in a draw after a very fast and exciting game. Neither side scored. For the E.E.F.C., Messrs. W. A. Purdom (captain), W. F. Collins, G. E. Hartimans as three-quarter backs, Messrs. F. Webb, jun., and L. Monteath as half-backs, Messrs. Knight, Bradberry, A. Webb and Brown as forwards, and Mr. R. G. Monteath as full back, played well; and for the Resistance F.C., Messrs. Parsons (captain), Gush, Bush, Hewett, the Lumleys, and the brothers Sargent were the most conspicuous.

The Glasgow Exhibition for 1888.—The plans, taking the prize, by competition, for the above exhibition were published last week. They are by Messrs. Campbell, Douglas and Sellars, of Glasgow, for a structure 880 feet in length and proportionate breadth. Special attention has been given to the matter of electric lighting, and a gallery, 140 feet by 50 feet is to be devoted to electric lighting machinery alone. The building is to be erected in the playground portion of the West End Park, immediately under the shadow of the University where Sir William Thomson has developed his many scientific inventions, so that there is every prospect of having electrical science well represented.

Electricity and Earthquakes.—Mr. George O'Brien, writing in the *Mining Journal*, distinguishes most of the earthquakes that occur on the western coast of South America as arising from the local action and volcanic exhalations in the Andes causing electrical currents down the valleys from east to west, and under the "made ground," which is derived from constant wearing down of the mountains. "The electric current travelling on the firm rock conducted by the moisture and water lying upon it, and thus in contact with the material possessing for it the greatest powers of conductivity, and from such fulcrum and firm basis the current shakes the made ground above it, with buildings thereon, the electric fluid then escaping into the atmosphere, animating all nature and eventually causing when in excess thunder and lightning." We may here remark that in the *Comptes Rendus* for March 21st, M. Ch. Naudin suggests that earthquakes may be due to the greater or less resistance which certain parts of the earth's crust present to the electric currents generated within the globe. He points out, further, that the countries visited by earthquakes are devoid of forests, which would favour the escape of the electricity.

The Largest Central Station.—The station at New Orleans of the Louisiana Electric Light and Power Company, of the Fort Wayne Jenney system, is said to be beyond question the largest in the world. There are 60 dynamos in use, principally 30 lighters. They supply 1,600 lights, 850 for the city and 750 to private consumers. There is one 28 × 60, and one 32 × 60 compound condensing Reynolds-Corliss engine, made by E. P. Allis & Co., with a combined 2,000 H.P. There are 20 boilers 6 × 16, manufactured by the Bass Foundry and Machine Works, of Fort Wayne, all set with Jarvis furnaces. The Munson belting in use is the largest ever made. The three belts are 42, 52 and 64 inches wide. The 64 inch belt is about 150 feet long. One of these belts travels 13,600 feet a minute. The shafting runs from 8 down to 4¼ inches diameter. The buildings are large. The dynamo room is 177 × 75 feet; the engine room 50 × 90; the boiler room 177 × 60. The engine room is now in course of completion. The rest of the station was built some time ago. The offices will be in the new part. It is interesting to note, says the *Electrical World* (which gives the particulars we have quoted), that the company formerly had small high speed engines, but have discarded them completely, using the slow speed for economy. They figure this way: High speed engines require about 4½ lbs. of coal per light per hour; low speed about 2½ lbs. On 1,600 lights this gives a saving of 3,200 lbs. an hour; or for eight hours 25,600 lbs., or nearly 12½ tons per day. This, at $4 a ton, is a saving of $50 a day. The company, therefore, thinks that the large engines, although they cost $50,000, or $30,000 less than the small ones, are a good investment.

NEW COMPANIES REGISTERED.

Self-Winding Clock Syndicate (Foreign Patent), Limited.—Capital, £15,000 in £10 shares. Objects: To acquire the patents for France and Belgium granted for "improvements in clocks and apparatus for actuating and controlling the same by electricity" (corresponding with the English patent, No. 15,500, A.D. 1884); and also the French, Russian, Belgian and Austrian patents granted for "improvements in synchronisers" (corresponding with the English patent, No. 7,548, A.D. 1885). Signatories (with one share each): C. E. Spagnoletti (electrical engineer), The Poplars, Aberdeen Place, N.W.; P. Fowler, 2, Queen Street Place; J. C. Bennett, 79, Queen Street, E.C.; H. T. McNeale, 113, Cannon Street; *F. L. Rawson, 11, Queen Victoria Street; *W. Leatham Bright, M.P., 118, Leadenhall Street; *J. A. Lund, 49, Cornhill. Directors' qualification, 25 shares, or £250 stock. The company in general meeting will appoint remuneration. Registered 1st inst. by Nash Field & Withers, 12, Queen Street, E.C.

Provincial Gas and Lighting Works, Limited.—Capital, £20,000, divided into 25 founders' shares of £1 each, and 779 ordinary shares of £25 each. Objects: To erect gasworks and works and apparatus for the supply, use, and application of electricity or electric light and power. Signatories: Hy. Hughes, 23, Martin's Lane, E.C., 2 founders' and 4 ordinary shares; J. H. Taylor, 15, Tokenhouse Yard, 2 founders' and 4 ordinary shares; E. R. Painter, 156, Larkhall Lane, 2 founders' and 4 ordinary shares; R. S. Mayne, 156, Larkhall Lane, 11 founders' and 2 ordinary shares; Hy. Arms, 95, Devonport Road, Shepherd's Bush, 2 founders' and 4 ordinary shares; J. A. Longest, 17, Upham Park Road, Chiswick, 2 founders' and 4 ordinary shares; E. J. Robinson, 7, John Street, Adelphi, 2 founders' and 4 ordinary shares; John Bull, New Lodge, Clapham Park, 2 founders' and 4 ordinary shares. The signatories are to appoint the first directors. The remuneration of the board is not to exceed £2 2s. for each attendance at board or committee meetings, and such further sum as may be voted in general meeting. Registered 4th inst. by R. S. Mayne, 156, Larkhall Lane, Clapham.

London Battery Company, Limited.—Capital: £100,000 in £5 shares. Objects: To take over the business of the London Battery Company, carried on by Mr. A. W. Armstrong at 83A, Farringdon Street, and to manufacture and deal in electrical and engineering apparatus and appliances. Signatories (with one share each): A. W. Armstrong, 83A, Farringdon Street; *G. Shenton, 17, Craven Street, W.C.; *J. Armstrong, Park Hill, Clapham; J. W. Watts, 74, Charlton Road, Fulham; F. C. Howard, 34, Fobstone Road, S.W.; E. Barcombe, 13, Sawfield Road, Hackney Road; *B. Hallett, 5, Bentinck Terrace, Regent's Park. Qualification for directors (other than the managing-director): 200 shares. The remuneration of the board will be determined by the company in general meeting. Registered 4th inst. by Hallett and Spottiswoode, 32, Craven Street, Charing Cross.

OFFICIAL RETURNS OF ELECTRICAL COMPANIES.

Brighton Electric Light Company, Limited.—The annual return of this company made up to the 29th ult., was filed on the 4th inst. The nominal capital is £25,000 in £5 shares. 1868 shares have been taken. These shares are fully paid, a call of 10s. per share having been paid on 1,600 shares since the last return. 8 shares were originally issued fully paid and 260 fully paid shares have been issued during the current year. Registered Office, Gloster Road, Brighton.

Jablochkoff and General Electricity Company, Limited.—By a letter dated 22nd ult., the Board of Trade has signified its approval of the name of this company being changed to the United Electrical Engineering Company. The letter was duly filed at Somerset House on the 1st inst.

Anglo-American Brush Electric Light Corporation, Limited.—An agreement dated 23rd ult., and filed on the 29th ult., provides for the allotment of 43 fully paid shares to shareholders in the Brush Midland Electric Light Company, Limited, in pursuance of an agreement 29th November, 1884.

Equitable Telephone Association, Limited.—The registered office of this company, formerly at 32, Craven Street, W.C., is now situate at 75, Queen Victoria Street.

* Signatories whose names are preceded by an asterisk are also directors.

CITY NOTES.

The Oriental Telephone Company, Limited.

THE report of the directors for the year ending 31st December, 1886, states that after setting aside £3,634 17s. 3d. in respect of the Indian guarantees to 31st December, the profit and loss account exhibits a balance to credit of £4,769 11s. 3d., including £2,402 15s. brought forward from 1885; the net profit for the past year being £2,366 16s. 3d. It is not proposed to deal with this balance at present.

The item £8,003 18s., at credit of revenue account, includes a sum of £1,296 6s., the amount of the company's guaranteed interest on the preferred shares held by itself in the Indian companies.

This sum forms part of the above-mentioned item of £3,634 17s. 3d. carried to debit of profit and loss, so as to show the total amount of guaranteed interest due by this company for the past year.

The directors are glad to be able to announce that the guarantee to the Bombay Company will expire in September of the current year, and that to the Bengal Company in June following, after which the deferred shares of both these companies held by this company will rank for dividend.

The progress made by the Bombay Company during the past six months is encouraging, but the income of the Bengal company is practically stationary. The local directors of these companies attribute much of the slow development in India to the obstructive and prohibitive policy of the Indian telegraph department. Your directors recognise that this has been a serious obstacle to telephone enterprise in that country, and they have on several occasions represented to the Government of India, as well as to the Secretary of State for India at home, the injury that is being done to this enterprise by the action of that department; so far, however, they have been unable to obtain much redress. Their best efforts will still be made to procure the relief asked for.

The returns from the exchanges worked directly by the company have on the whole been satisfactory. The expenses at all stations have been reduced to a minimum, consistent with efficiency.

The preferred shares held in the Telephone Company of Egypt have earned six per cent., as against five per cent. the previous year, and it is fully expected that the business of the current year will give equally good, if not better results.

The China Company in which this company has also a large interest has been able to pay its interest on debentures, and reduce the deficit from former years' working, which it is hoped will be finally extinguished during the current year.

The question of the company's patents in Australasia has again occupied much of the time of the Board. Investigations into the position have necessarily been very slow, but the directors fully expect shortly to obtain a recognition of the rights possessed by the company.

The Telephone Company of Ireland, Limited.

THE following report of the directors for the year ending December 31st, 1886, of this company, of which Mr. E. Dwyer Gray, MP., is chairman, has just been issued:

The number of wires, exchange and private, under rental within the Dublin district and suburbs, upon December 31st, 1885, was 878. On December 31st, 1886, the number was 915. The business thus continues to show a steady and satisfactory progress.

The heavy snow storms and severe weather of the past winter caused no damage of any consequence to the company's wires, and the whole system has again been peculiarly free from breakage or accidents.

During the year the trunk lines to the principal suburbs around Dublin have been completed, and by offering exceptional facilities for the connection of the residences of subscribers with the central exchange, it is expected that the suburban business of the company will be greatly developed. Trunk wires to other Dublin suburban districts will be erected as circumstances may justify the necessary outlay.

In the month of April last an exchange was opened at Dundalk as an experiment upon the call-fee system, and the directors are gratified to be able to announce that it has already developed sufficiently to pay its way. During the current year, no doubt, it will show a profit upon the working.

Encouraged by the result of this experiment at Dundalk, the directors have it now in contemplation to open exchanges in other towns upon the same system.

In order to provide the capital necessary to meet the expenditure requisite for the increasing business of the company in Dublin and its suburbs, and for the establishment of the proposed additional exchanges, the directors consider it desirable that they should have the power of raising such capital, by the issue of additional shares instead of by calling up the unpaid balance due upon the 29,776 preference shares partly paid, in the event of their deeming it desirable in the interest of the shareholders that such a course should be adopted at the time additional capital may be required. A resolution having that object in view will, therefore, be submitted to the meeting in the terms of the accompanying notice.

The amount standing to the credit of net revenue account, including the balance of £98 7s. 6d. brought from last account, amounts to £3,629 2s. 4d., against £3,078 16s. 10d. for the year 1885. Out of this sum there has been paid the interim dividend upon the preference shares for the half-year ended June 30th, 1886 (£779 9s. 9d. paid in July last), also the interim dividend upon the ordinary shares (£656 5s. 0d. paid in August), leaving an available balance of £2,193 7s. 7d., as shown in the balance sheet, since reduced, by payment (on January 14th) of the dividend upon the preference shares for the second half of the year, to £1,355 4s. 8d. This would permit of the payment of an increased dividend on the ordinary shares at the rate of 1½ per cent. for the second half of the year, as against ¾ per cent. for the corresponding half of 1885; but the directors think it more prudent to substantially strengthen the reserve fund. They therefore propose to allocate the balance as follows:—For the payment of a dividend on the ordinary shares at the same rate as for last half-year—namely, ¾ per cent. per annum, £656 5s., and to place to the credit of the reserve fund, £369 18s. 3d. (being 10 per cent. upon the net profits of the year), carrying forward the balance of £329 1s. 5d. to credit of the current year, as against £98 7s. 6d. brought in from 1885.

The following resolution will be submitted to the forthcoming meeting:—"That the directors be and they are hereby authorised to issue 25,000 preference shares of £1 each, being the unissued portion of the total of 75,000 preference shares authorised by the Articles of Association."

Indo-European Telegraph Company, Limited.—The directors have determined, subject to audit, to recommend the payment of a dividend for the six months ended December 31st, 1886, of 17s. 6d. per share, making, with the interim dividend already paid, 6 per cent. for the year and a bonus of 20s. per share, both tax free, making in all 10 per cent. for the year. The dividend and bonus will be payable on and after May 1st next.

Anglo-American Telegraph Company, Limited.—The directors have resolved to declare an interim dividend for the quarter ending 31st March, 1887, of 5s. per cent. on the ordinary stock, and 10s. per cent. on the preferred stock, less income tax, payable on the 2nd May, to the stockholders registered on the books of the company on 31st March, 1887.

The Direct United States Cable Company, Limited.—The board of this company has resolved upon the payment of an interim dividend of two shillings per share, free of income tax, being at the rate of 2 per cent. per annum, for the quarter ending 31st March, 1887; such dividend to be payable on and after the 23rd instant.

Foreign Pilsen Electric Light and Power Company, Limited.—The annual general meeting of this company was held on Thursday last week, and a dividend at the rate of 1 per cent. per annum was declared for the year ending February 28th, 1887.

TRAFFIC RECEIPTS.

The Cuba Submarine Telegraph Company, Limited. The number of messages passing over the lines of this company during the month of March was 4,775, estimated to produce £3,650, against 3,944 messages, producing £3,345 in the corresponding month of last year. The receipts for the month of December, estimated at £3,100, realised £3,125.

The West India and Panama Telegraph Company, Limited. The estimated receipts for the half-month ended the 31st March are £2,216, as compared with £3,263 in the corresponding period of 1886. The December receipts, estimated at £5,296, realised £5,311.

The Great Northern Telegraph Company, Limited. The receipts for March, 1887, were £21,600; 1st January to 31st March, 1887, £61,200; in the corresponding months, 1886, £58,080; and of 1885, £64,400.

The Eastern Extension, Australasian and China Telegraph Company, Limited. The receipts for March amounted to £38,177, against £37,804 for the corresponding period of 1886; increase, £373.

The Direct Spanish Telegraph Company, Limited. The estimated receipts for the month of March were £1,850, against £1,760 in the corresponding period of last year.

The Eastern Telegraph Company, Limited. The receipts for March amounted to £49,797, and to £53,016 for the corresponding period of 1886.

ABSTRACTS OF PUBLISHED SPECIFICATIONS, 1886.

1196. "Improvements in actuating mechanism for electrostatic generators, and in applications thereof." J. G. LORRAIN. Dated January 26. 6d. Relates to improvements in actuating mechanism for electrostatic generators, and has for its object improved methods of working the same by means of fluid pressure. The claims are 22 in number.

1999. "Improvements in and connected with electric lamps for use for lighting in mines, railway carriages, and other places, and means for indicating the presence of fire-damp or explosive gases in mines or other places." J. W. SWAN. Dated February 11. 1s. 1d. Consists in the combination with a portable primary or secondary battery of an incandescent electric lamp or lamps and other appliances, including if desired a fire-damp indicator, and giving great convenience in construction and freedom from danger of ignition of combustibles, gases, or other materials by the lamp when in use. The claims are 11 in number.

2290. "Improvements in the construction of electric testing apparatus." J. S. Raworth. Dated February 17. 8d. Consists in certain improvements in the construction of galvanometers and detectors whereby their cost is reduced, their efficiency and handiness increased, and their repairs rendered both easy and inexpensive.

2785. "A safety electric lamp for coal miners." W. J. Smith. Dated February 26. 4d. Claim:—The principle of interposing wire gauze between the carbon of an incandescent lamp and the exhausted envelope containing it, with the view of preventing the ignition of any combustible gas or gases or coal dust that may surround the said lamp at the time it may be broken, and during the consequent combustion of the said carbon.

2932. "Improvements in galvanic batteries." A. Schanschieff. Dated March 1. 6d. Claims:—1. A battery cell with elements of zinc and carbon in contact with peroxide of lead or peroxide of manganese and immersed in a liquid obtained from mercury and sulphuric acid, substantially as described. 2. A battery cell with elements of zinc and carbon, the latter being in contact with peroxide of lead or peroxide of manganese, and immersed in a sulphate solution, substantially as described. 3. A battery cell with elements of zinc and carbon, the latter being in contact with peroxide of lead or peroxide of manganese, these oxides being changed by the sulphate solution under galvanic action into lower oxides, and again reconstituted into their higher form by the action of chlorides.

2956. "Improvements in electro-motors and dynamo machines." M. Immisch. Dated March 2. 8d. This invention relates to the employment of the same form of commutator as that described in the inventor's previous application for letters patent No. 6,037, dated 16th May, 1885, the object being to apply such form to dynamos and motors in which the armature coils are all in closed circuit instead of forming separate open circuits as in the previous application above referred to. Claims:—1. In dynamos and electro-motors the employment of a double commutator the segments of which have an angular displacement in relation to each other such that the line of division between two segments in one series is opposite the middle of a segment in the other series, the ends of the armature coils being connected to consecutive segments in the same series, for the object of enabling one half of the armature to be placed either in parallel or in series with the other half, substantially as and for the purposes described and shown in the drawings. 2. In dynamos and electro-motors the employment of a double commutator the segments of which have an angular displacement in relation to each other such that the line of division between two segments in one series is opposite the middle of a segment in the other series, the ends of the armature coils being connected to consecutive segments, belonging to different series, for the object of short circuiting upon itself a portion of the armature wire which surrounds that part of the core where the poles are formed by the active part of the wire, substantially as and for the purposes described and illustrated in the drawings.

3106. "Improvements in electric and magneto bells, and apparatus to be used in connection therewith. H. P. F. Jensen, B. W. Webb, and J. Jensen. Dated March 4. 1s. 1d. In the specification of former letters patent granted 3rd October, 1882, No. 4712, the inventors have described electric bells wherein the clapper or hammer and the armature are secured to each other and suspended within the bell at or near the top thereof. One object of the present invention is to improve the construction and increase the efficiency of bells of this kind. Another object of the said invention is to provide very simple and cheap electric bells for domestic or other purposes. The claims are 27 in number.

3183. "Improvements in and connected with dynamo-electric machines." T. A. Garrett. Dated March 6. 8d. Claim:—A dynamo-electric machine or motor wherein a magnetic and conducting armature in the form of a cylindrical shell revolves in a magnetic field so arranged that lines of magnetic force pass radially through the shell and electrical currents pass longitudinally along it, substantially as described.

3199. "Improvements in telephones." J. Stuart. (Communicated from abroad by J. Hutinet and P. Felix, both of Paris.) Dated March 6. 8d. Consists essentially in the employment of two free vibrating membranes acting in combination with a magnet and coils arranged as explained. The claims are 7 in number.

3340. "Improvements in electric arc lamps." W. H. Trentham. Dated March 9. 6d. Claims:—Firstly. The construction of a double arc lamp wherein the solenoids are arranged side by side, having tapering iron cores free to slide lengthwise therein, said cores carrying at their lower ends the top carbons of the lamp, in combination with the two sliding frames carrying the lower carbons, said frames working on opposite sides, one above the other, on the same guide bars as described and shown in the drawings. Secondly. The mechanical "cut-out" or switch for automatically switching the current from the first carbon burned to the second without breaking the circuit, as described and as shown in the drawings.

3360. "An improved electric alarm clock." J. Warmisham. Dated March 10. 6d. An ordinary timepiece clock fit up with a small brass alarm dial, which as a pin or rivet in. The clock is connected with wires running to a Le Clanch (*sic*) battery and an elictric (*sic*) bell. The clock when in motion carries the small brass dial round, and the pin or rivet coming in connection with a piece of brass (attached to the wires from the side of the clock), thus completing the connection and causeing the bell to ring at the time set, and keep on ringing till it is stopped, which is done by disconnecting it with the switch on the side of the clock. The claims are 3 in number.

3476. "Improvements in galvanic batteries." A. Schanschieff and G. R. Fludder. Dated March 11. 8d. The object of this invention is to secure and connect the elements of the battery so that they may be readily replaced when they become unserviceable and so that comparatively thin rolled or sheet zinc may be more conveniently employed than heretofore. The claims are two in number.

3969. "An improved switch and resistance regulator for dental electric motors." A. M. Clark. (Communicated from abroad by the firm of Schäfer and Montanus, of Frankfort-on-Main, in the Empire of Germany, through their agents, Wirth and Company, of the same place.) Dated March 20. 8d. Claim:—The described switch and resistance regulator for dental electric motors mounted on the tool holder or sheath of the tool shaft, and constructed of a rotating flanged contact ring in combination with a series of contact springs to which are respectively connected copper and German silver wires, so combined and arranged that by turning the ring it will make contact with one, two, or more of the springs, in such manner that the motor can be switched on and off, and its velocity regulated as specified.

4057. "Improvements in voltaic piles and accumulators." P. Hadden. (Communicated from abroad by J. Crosse, of Paris.) Dated March 23. 6d. Claims:—1. The combination of the negative and positive electrode of each element, with a plate of cocoa-nut fibre placed between the electrodes, and saturated with the necessary chemical reagent or reagents. 2. The combination of the negative and positive electrode with a plate of compressed cork placed between the electrode and saturated with the necessary chemical reagent or reagents, substantially as described.

4130. "Improvements in and relating to the counting and recording of the number of messages transmitted over telephonic circuits. J. D. Miller. Dated March 24. 1s. 3d. The inventor registers automatically the successive connections made in the telephone exchange or in the subscriber's instrument or elsewhere in a circuit by means of an electrical counter or recording instrument operated by the closing or opening of said circuit or of a local circuit in the act of making connection between subscribers or of bringing the subscriber's telephone into use. The claims are four in number.

PROCEEDINGS OF SOCIETIES.

Physical Society, March 26th, 1887.

Prof. Balfour Stewart, President, in the Chair.

Mr. Edmund van Autel was elected a member of the society.

The following paper was read, "On the Production, Preparation and Properties of the Finest Fibres," by Mr. C. V. Boys, M.A.

The enquiry into the production and properties of fibres was suggested by the experiments of Messrs. Gibson and Gregory on the "Tenacity of Spun Glass," described before the society on February 12th, and the necessity of using such fibres in experiments on which Prof. Rücker and the author are engaged.

The various methods of producing organic fibres such as silk, cobweb, &c., and the mineral fibres, volcanic glass, slag wool and spun glass were referred to, and experiments shown in which masses of fibres of sealing wax or Canada balsam were produced by electrifying the melted substance.

In producing very fine glass fibres the author finds it best to use very small quantities at high temperatures, and the velocity of separation should be as great as possible. The oxyhydrogen jet is used to obtain the high temperature, and several methods of obtaining a great velocity have been devised. The best results obtained are given by a cross-bow and straw arrow, to the tail of which a thin rod of the substance to be drawn is cemented. Pine is used for the bow, because the ratio of its elasticity to its density (on which the velocity attainable depends) is great. The free end of the rod is held between the fingers, and when the middle part has been heated to the required temperature the string of the cross-bow is suddenly released, thus projecting the arrow with great velocity and drawing out a long fine fibre. By this means fibres of glass less than $\frac{1}{10000}$ of an inch in diameter can be made.

The author has also experimented on many minerals, such as quartz, sapphire, ruby, garnet, feldspar, fluor spar, angite, emerald, &c., with more or less success. Ruby, sapphire and fluor spar cannot well be drawn into fibres by this process, but quartz, angite and feldspar give very satisfactory results. Garnet, when treated at low temperatures, yields fibres exhibiting the most beautiful colours.

Some very interesting results have been obtained with quartz from which fibres less than $\frac{1}{100000}$ of an inch in diameter have been obtained. It cannot be drawn directly from the crystal, but

has to be slowly heated, fused, and cast into a thin rod, which rod is attached to the arrow as previously described.

Quartz fibre exhibits remarkable properties, as it seems to be free from torsional fatigue, so evident in glass and metallic fibres, and on this account is most valuable for instruments requiring torsional control. The tenacity of such fibres is about 50 tons on the square inch.

In the experiments on the fatigue of fibres, great difficulty was experienced to obtain a cement magnetically neutral, and sealing wax was found the most suitable.

An experiment was performed illustrating the fatigue of glass fibres under torsion, and diagrams exhibited showing that the effect of annealing them is to reduce the sub-permanent deformation to about $\frac{1}{10}$ its original amount under similar conditions.

Annealing quartz fibres, does not improve their torsional properties, and renders them rotten.

Besides the use of quartz for torsional measurements, the author believes that quartz thermometers would be free from the change of zero, so annoying in glass ones. He exhibited an annealed glass spiral capable of weighing a millionth of a grain fairly accurately, and also a diffraction grating made by placing the fine fibres side by side in the threads of fine screws. Gratings so made give banded spectra of white light.

The author regretted that his paper was so incomplete, but thought the results already obtained would be of interest to the society.

Prof. W. G. ADAMS congratulated the author on his most interesting paper and considered the results to be of great importance. He believed the banded spectra exhibited by the grating were probably due to internal reflection within the fibres.

Mr. CUNYNGHAME asked whether the glass mirror used in the torsional experiments was magnetic, to which the author replied that this was probable, but even this assumption did not explain all the peculiarities observed.

A paper by Prof. Pickering was postponed till the next meeting on April 23rd.

CORRESPONDENCE.

Single Needle Duplexing.

In your issue of the 25th inst. I observe an article on "Duplexing Single Needles" on the Caledonian Railway, and that the credit of first effecting such working in a practical manner is awarded to the telegraph superintendent of that company. As there is evidently some mistake in this matter, permit me space in your columns for a few remarks by way of correction. If my memory serves me correctly, it was in the summer of 1873, or close upon 14 years ago, that I, under the direction of my father, Mr. E. Gilbert, experimented on and established a system of duplex single needle between Edinburgh and Glasgow on the North British Railway.

Fortunately we had on the circuit no intermediate stations to shut out from communication, which of course could not but add to its efficiency; still, the ever varying resistance of the line wire necessitating constant adjustment of the rheostat, the inability of the receiving clerk to obtain a repetition of any doubtful words without the aid of the sending clerk, the important fact that more clerks are required for the duplex than for the ordinary single needle working, and that the expedition in the former, all things considered, is less rather than greater, the single needle duplex was abandoned as reverse to advantageous to the railway telegraph service. If any corroboration of the wisdom of this course is wanting, it may be gathered from the coincidence that in the 14 years since elapsed neither the Postal Department nor any railway company have reverted to the system, and that the Caledonian Company should have disinterred it now and have published the arrangement as something new and promising to the railway service is, to say the least, a sorry mistake.

Arthur E. Gilbert.

March 30th, 1887.

I observe your article in the Journal of 25th March on the subject of duplexing ordinary single needle instruments which the Caledonian Railway Company has introduced, and am very glad to see that this system is likely to be of such value. I think it only right, however, to inform you that this company had a single needle speaking circuit working between Edinburgh and Glasgow upon the duplex principle between 13 and 14 years ago. It was worked for some time with satisfactory results, but was discontinued in consequence of more staff being required at each end of the circuit. I may state that our staff are much more expert at single needle working now than they were then, and should the necessity arise for duplex working, we should be able to carry it on with the ordinary staff at each end.

A. F. Clement,
Telegraph Supt., N. Br. Railway Co.

April 1st, 1887.

Faults in Submarine Cables.

In your note on my letter published in your last issue you point out to me that "G. P. cores of cables are sometimes manufactured without any kind of compound between the layers."

I *presume* you refer to the ingenious system of Messrs. Siemens Brothers, which system I had in mind when, with reference to the universal adoption of Chatterton and Willoughby Smith's compound for cementing together the separate coats of gutta-percha, I stipulated "*where it is laid on in more than one coating.*"

I believe that Messrs. Siemens's method of covering the conductor with insulating material is some modification of the mode described in the provisional specification of Mr. J. C. L. Loeffler, No. 905, A.D. 1880, in which some form of *multiple* die is employed in the covering machine.

I have *understood* that a *multiple* die was also used for covering wires some 20 years ago by one of the Hancock's, at West Ham.

It appears to *me* that any system of covering wires by means of a *multiple* die is that, *practically*, of covering the conductor to a required total thickness in *one* coating or layer; if this view be correct, it would in itself, perhaps, sufficiently explain the disuse, which you mention, of any compound "*between the layers.*"

Now, a system of covering the conductor to a given thickness in only *one* coating of G. P. has, certainly, the advantage of abolishing the necessity of any adhesive compound (with its unavoidable "masking" properties) as required between *a number* of layers; besides avoiding the detrimental effect which the tar in any such compound has on the insulating properties of gutta-percha.

Against these advantages, however, there must always be, I should think, an increased liability in any multiple die system of the separate *streams* of gutta-percha not adhering properly as they pass through the die.

There is also, I should imagine, the great disadvantage of the conductor having a greater chance of becoming otherwise than concentric in any part of its insulating envelope compared to where the same thickness of G. P. is laid on in several separate coats.

Charles Bright, Jun.

April 4th, 1887.

Sparking in Telegraphic Relays.

In the communication of Mr. Moon, on "Sparking in Telegraphic Relays," in your last issue, one cause is given as the low internal resistance of the batteries.

In the concern in which I am employed, we use alternating contacts with two batteries of 140 volts potential and 35 ohms internal resistance each, and there is no sign of arc, sparking, oxidation, contacts drawn out to fine points or any of the other disturbances mentioned.

I think, therefore, that the theory propounded and the formula given for the correction of the battery resistance is not of universal application, but only suitable to apparatus of a certain design.

Wm. Clark Fisher.

April 3rd, 1887.